



The sPhenix / fsPhenix / EIC Detector simulation code in its new home

Jin Huang (BNL)

Overview

- ▶ Finally, the sPHENIX/fsPHENIX/EIC (a.k.a ePHENIX) software universe divorced with traditional PHENIX software, and moved to open source website
 - sPHENIX software framework:
<https://github.com/sPHENIX-Collaboration>
 - ePHENIX addition:
<https://github.com/EIC-Detector/coresoftware-eic>
- ▶ Taking this opportunity updated fsPHENIX/ePHENIX simulation with the updated sPHENIX design

Running simulation in new sPHENIX universe on RCF

- » Based on sPHENIX tutorial by Chris Pinkenburg (BNL)
<https://indico.bnl.gov/conferenceDisplay.py?confId=1145>

With addition of ePHENIX software repository set up by Nils and I

Chris' sPHENIX Geant4 tutorial

- ▶ <https://indico.bnl.gov/conferenceDisplay.py?confId=1145>
- ▶ Detailed example to
 - login onto RCF/sPHENIX environment
 - check out sPHENIX core software, compile (usually already in nightly-build)
 - Run tutorial examples
- ▶ Want to try it on other computer than RCF?
 - Although not officially supported, you are welcome to try
 - Let us know your experience

Try out the EIC (a.k.a. ePHENIX) addition

- ▶ login onto sPHENIX RCF environment
 - Log into your rcf account
 - Make some directory and cd to it
 - Source the sphenix setup script:
`source /opt/sphenix/core/bin/sphenix_setup.csh -n`
 - Set up git (if you haven't done so already):
`git config --global user.name "Your Name Comes Here"`
`git config --global user.email you@yourdomain.example.com`

This proxy is needed in rcf, the transparent proxy seems to have issues

```
git config --global http.proxy http://192.168.1.165:3128
```

Try out the EIC (a.k.a. ePHENIX) addition

- ▶ Check out ePHENIX addition
 - Check out the repository
`git clone https://github.com/EIC-Detector/coresoftware-eic.git`
 - Enter the directory with ePHENIX macro:
`cd coresoftware-eic/macros/`
 - Here you will find all macros to run ePHENIX Geant4 part
Quick view on GitHub:
<https://github.com/EIC-Detector/coresoftware-eic/tree/master/macros>

Try out the EIC (a.k.a. ePHENIX) addition

▶ Give a spin with two DIS events

```
[jinhuang@rcas2070 macros]$ root  
root [0] .x Fun4All_G4_ePHENIX.C(2)  
..... Running .....
```

Here, 1st parameter is number of event to process.

1 event means give an event display (faster to run in a direct ssh session. Example later)

Default output is an quick evaluation file to inspect GEM hits:

```
-rw-r--r-- 1 jinhuang rhphenix 29K May 19 20:38 G4ePHENIX.root
```

```
[jinhuang@rcas2070 macros]$ root G4ePHENIX.root
```

```
root [1] T->Show(0)
```

```
=====> EVENT:0
```

```
..... Next page
```

Open root file and quickly inspect the results

```
root [1] T->Show(0)
```

```
=====> EVENT:0
```

```
n_G4HIT_GEMSTATION0 = 3
```

```
G4HIT_GEMSTATION0 = 3
```

```
G4HIT_GEMSTATION0.fUniqueID = 0, 0, 0
```

```
G4HIT_GEMSTATION0.fBits = 50331648, 50331648, 50331648
```

```
G4HIT_GEMSTATION0.x[2] = -4.449482 , -4.531405
```

```
, -6.980275 , -7.104282
```

```
, 5.616087 , 5.716170
```

```
.... Also in y, z, t,.....
```

3 hits in the first GEM station

```
G4HIT_GEMSTATION0.layer = 4294967295, 4294967295, 4294967295
```

```
G4HIT_GEMSTATION0.hitid = 2, 3, 4
```

```
G4HIT_GEMSTATION0.trackid = 12, 11, 9
```

```
G4HIT_GEMSTATION0.edep = 0.000000, 0.000001, 0.000001
```

```
....
```

```
n_G4HIT_GEMSTATION1 = 2
```

```
G4HIT_GEMSTATION1 = 2
```

```
....
```

```
n_PHG4Particle = 19
```

```
PHG4Particle = 19
```

```
PHG4Particle.fname = e-, anti_proton, neutron, pi-, anti_neutron, neutron, pi-, pi+, pi+, pi-, pi+, pi+, gamma, e-
```

```
PHG4Particle.fpid = 11, -2212, 2112, -211, -2112, 2112, -211, 211, 211, -211, 211, 211, 22, 22, 22, 22, 22, 22, 22, 11
```

```
PHG4Particle.fpx = -0.288157, 0.300443, 0.147239, 1.09091, -0.299606, -0.773975, 0.013641, -0.355005, 0.393898, 0.0496556, -0.232044, -0.393018, 0.216952, 0.0387981, -0.11403, -0.143604, 0.0355097, -0.0735285, -0.00146802
```

```
....
```

```
PHG4Particle.trkid = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 10262
```

```
PHG4Particle.vtxid = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 2, 2, 3, 3, 4
```

```
.....
```

```
n_PHG4VtxPoint = 5
```

```
PHG4VtxPoint = 5
```

```
... In the order of 0, 1, 2, 3, 4
```

```
PHG4VtxPoint.vx = 0, 3.4898e-05, -0.000185995, -6.31931e-06, -3.45825
```

```
.... Also in vy, vz ....
```

```
PHG4VtxPoint.t0 = 0, 467400, 320165, 30413.4, 9.91365
```

hits location, energy, etc

Use this to find out parent particle

Continue on GEM station 1, 2, ...

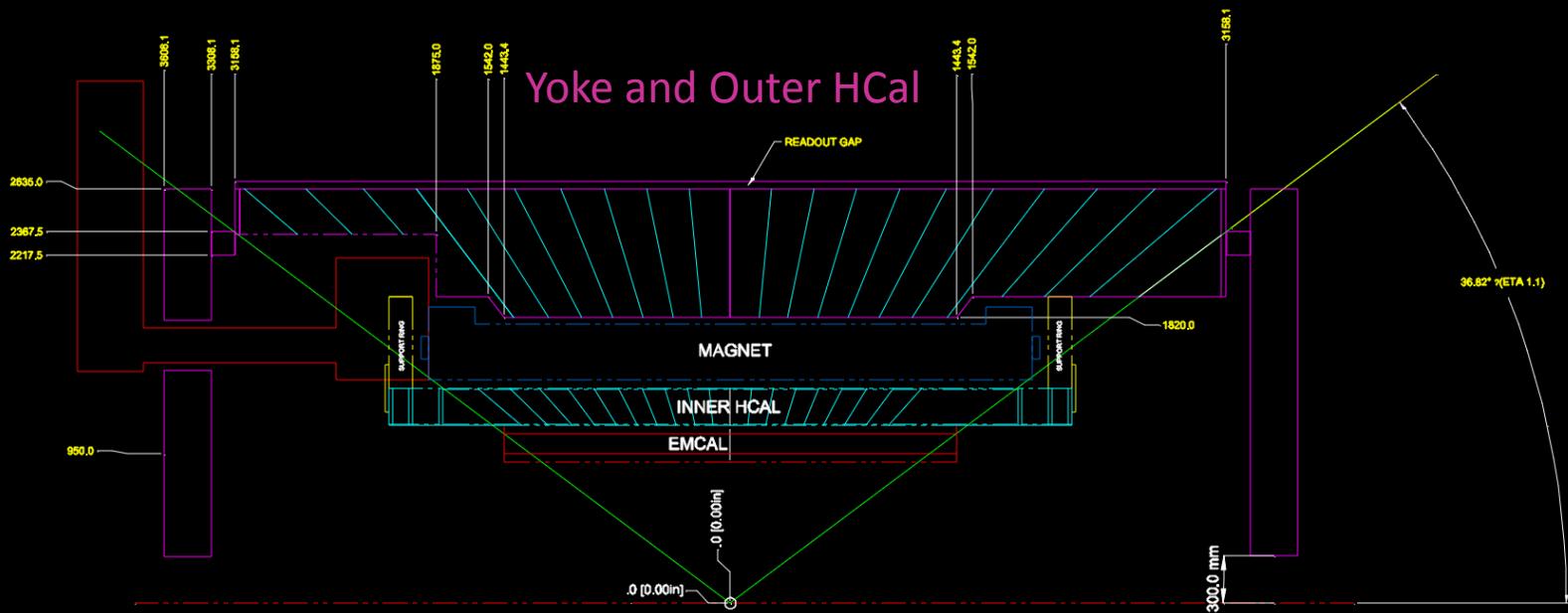
Parent particles in Geant4

Parent particles' kinematics

Use this to find out its vertex

Update geometry to new sPHENIX proposal

- » Update sPHENIX proposal and reference design:
[arXiv:1501.06197 \[nucl-ex\]](https://arxiv.org/abs/1501.06197)

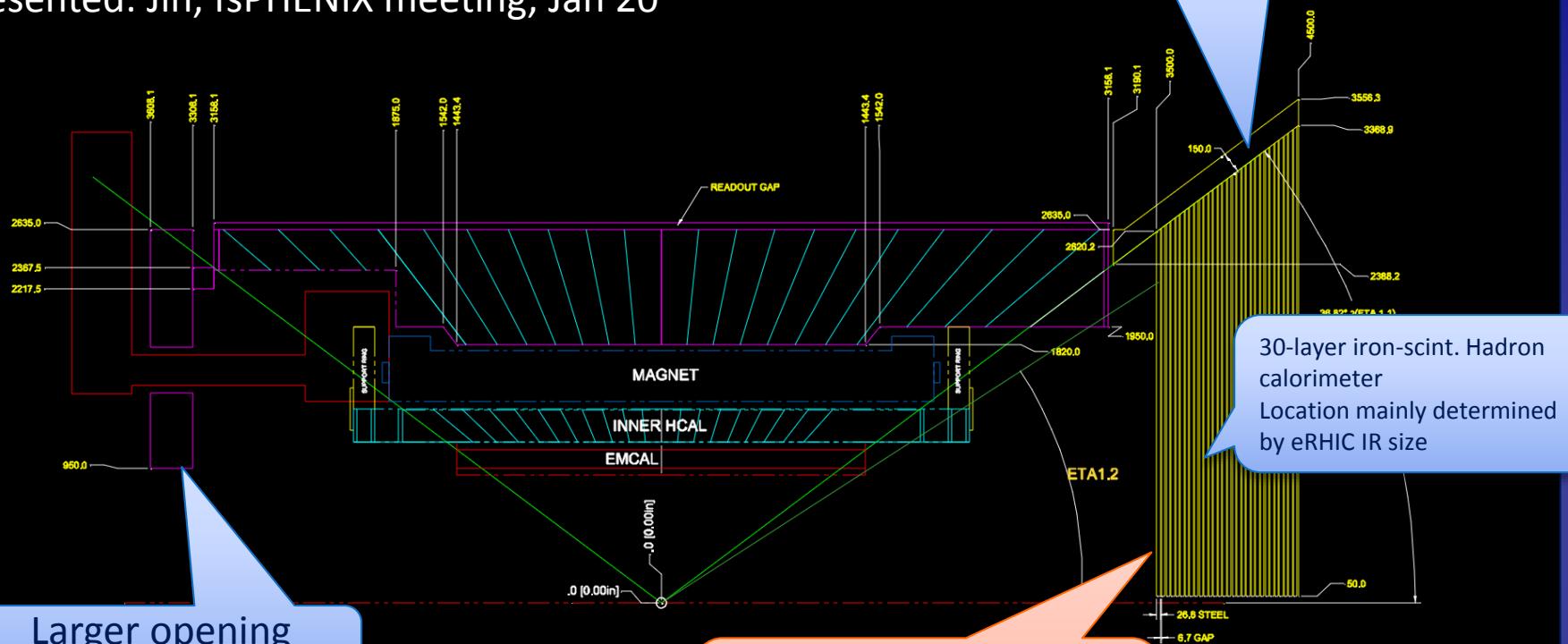


A recently updated sPHENIX mechanical drawing ➤

HCal geometry is significantly revised

End-door design

Lampshade magnet



Larger opening
(R95cm) for DIRC

Front surface ($z=3.5m$)
NOT so different from
end-door!!

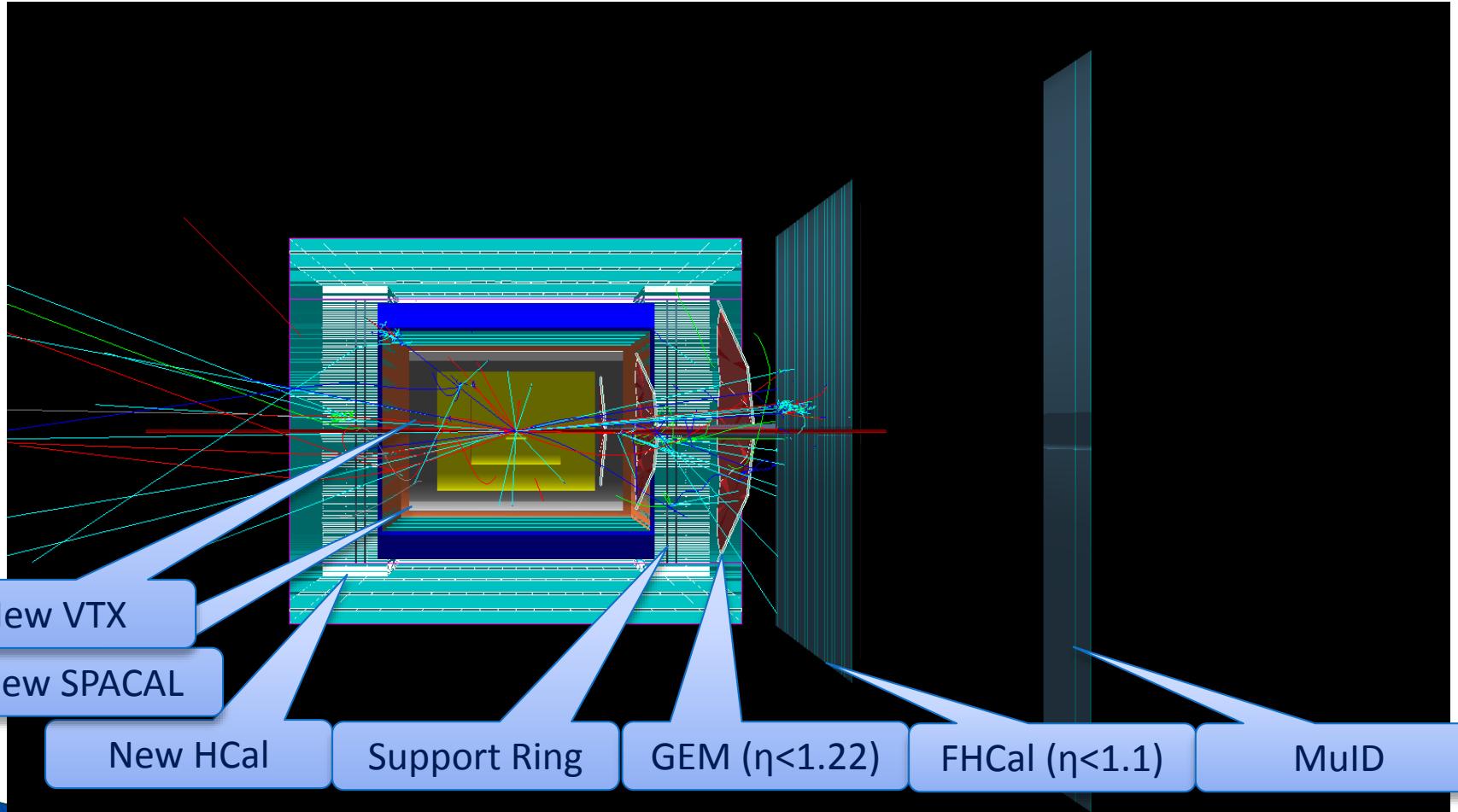
New forward spectrometer design ➤

Also very good magnetic field balance as shown by Nils

Updated Geant4 Model for fsPHENIX

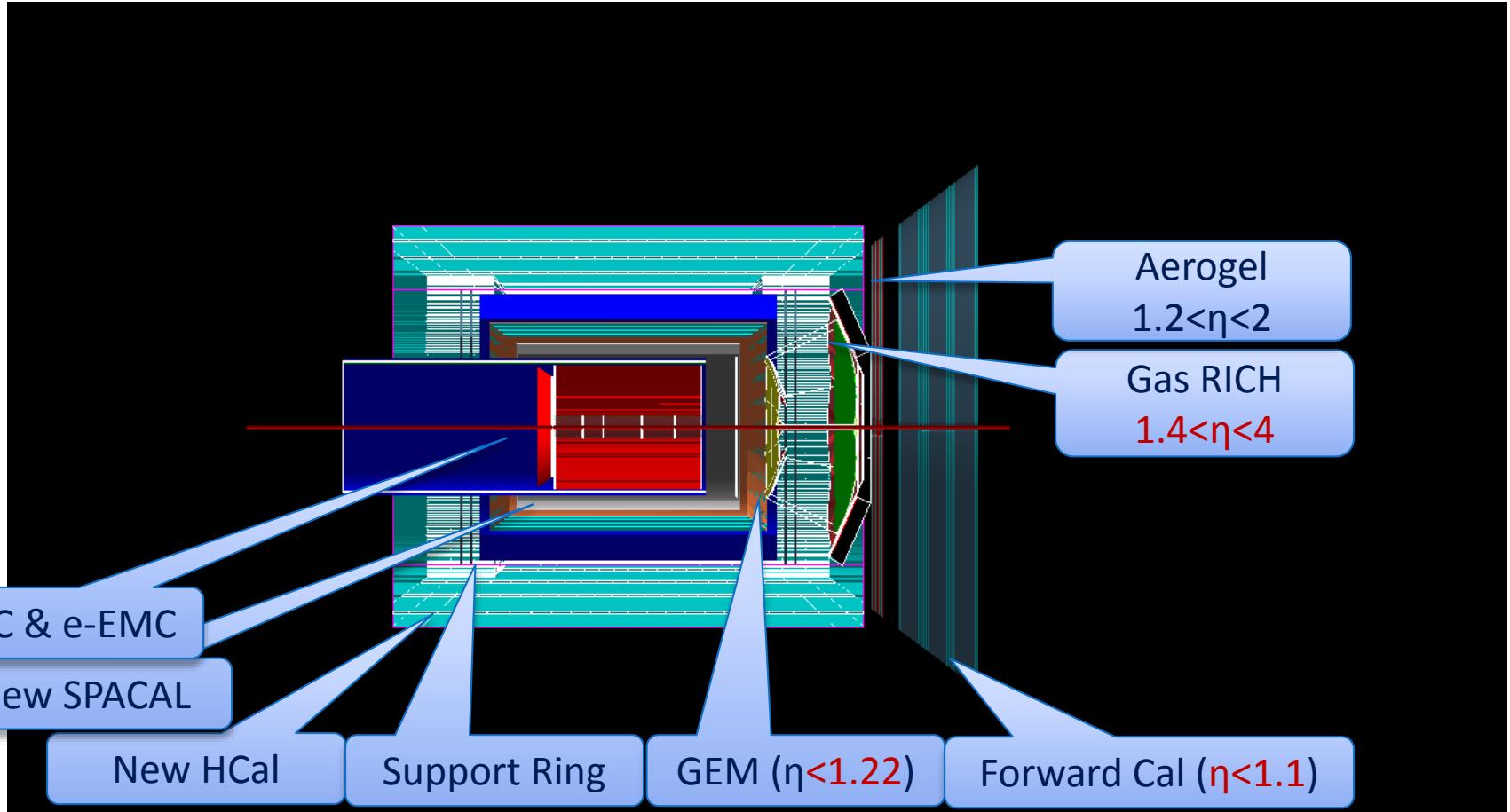
Available under GitHub/[EIC-Detector](#):

coresoftware-eic/macros/Fun4All_G4_fsPHENIX.C



Updated Geant4 Model for ePHENIX

Available under GitHub/[EIC-Detector](#):
coresoftware-eic/macros/Fun4All_G4_ePHENIX.C



Summary

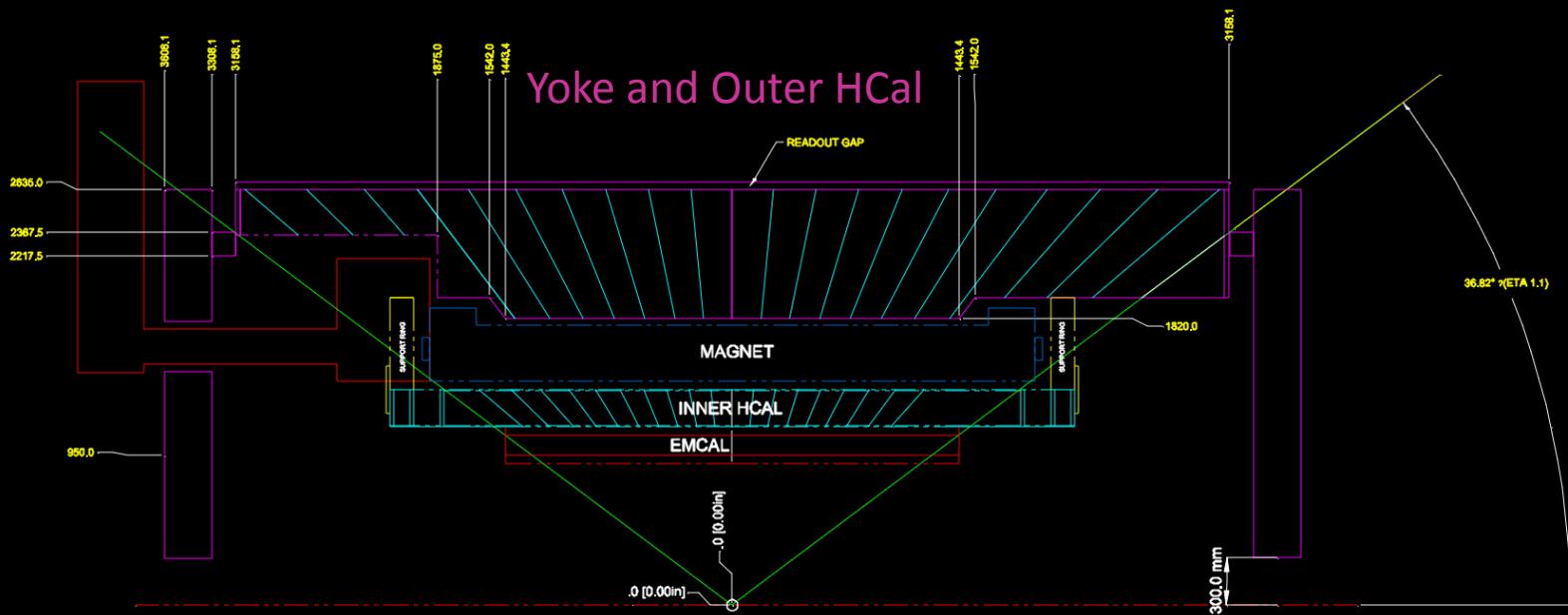
- ▶ sPHENIX/fsPHENIX/ePHENIX simulation software being moved to GitHub
 - Publicly available for download, still controlled submission
 - Divorcing software universe with PHENIX universe on RCF
 - Welcome for early trial and feedbacks.
- ▶ Updated fsPHENIX and ePHENIX geometry w.r.t. updated sPHENIX reference design
 - New central EMCal and hadron calorimeter with updated details of sPHENIX design
 - Forward spectrometer start with $\eta = +1.22$
 - Forward gas RICH start with $\eta = 1.4$

Extra Stuff



Update to new sPHENIX and forward arm design





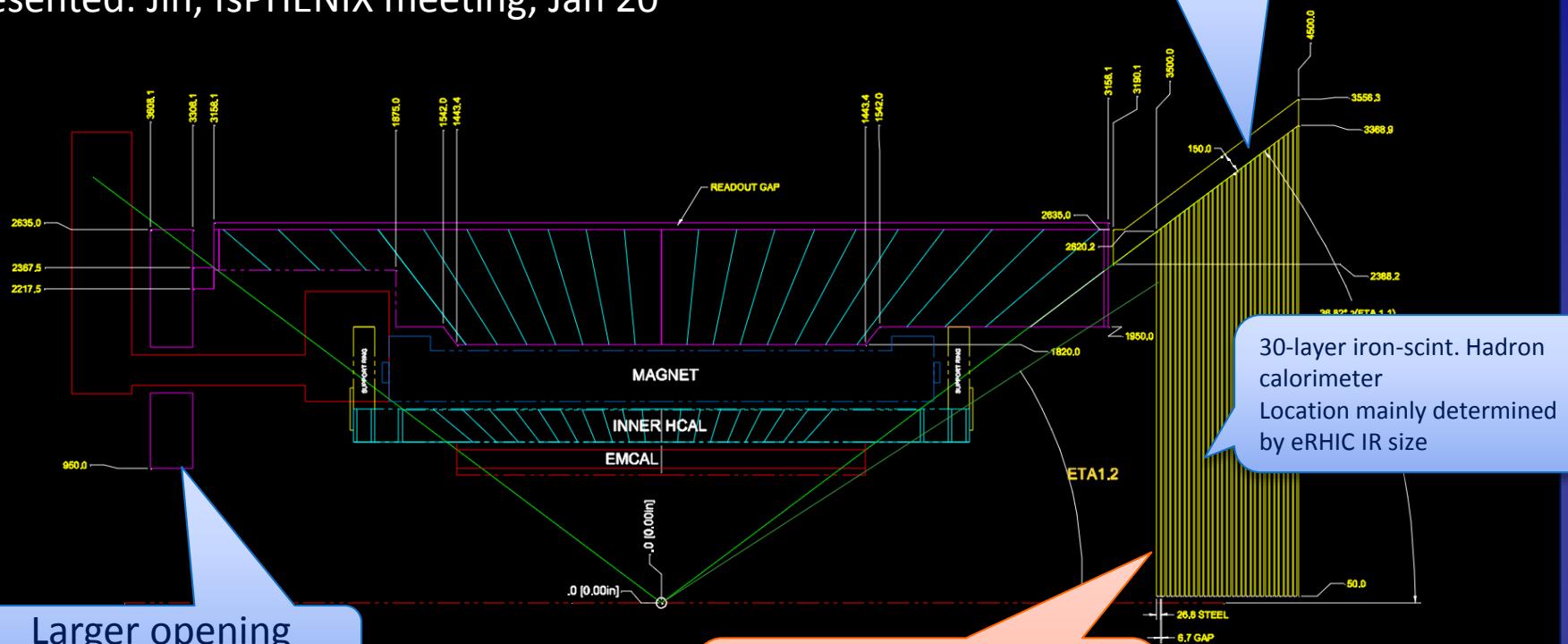
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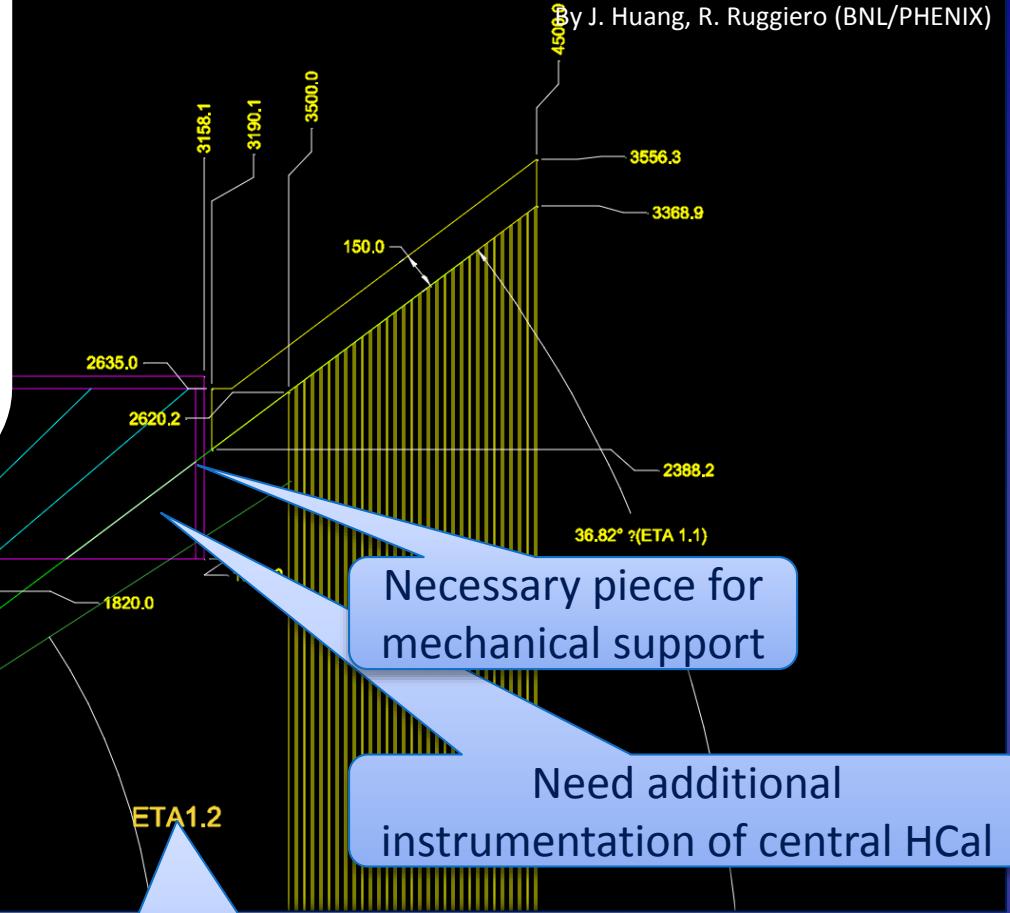
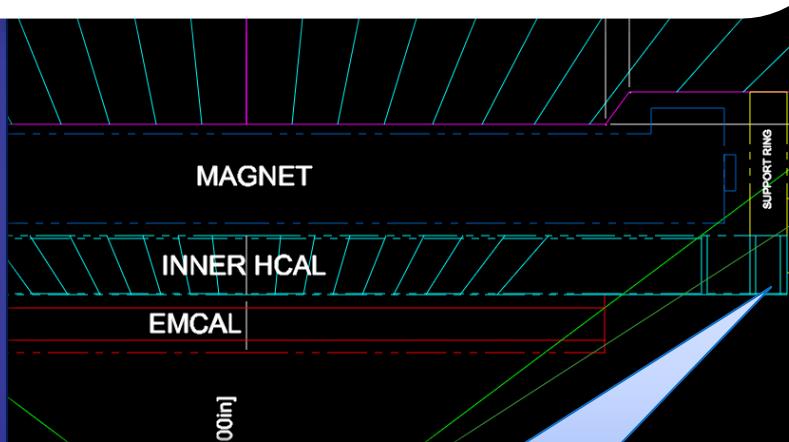
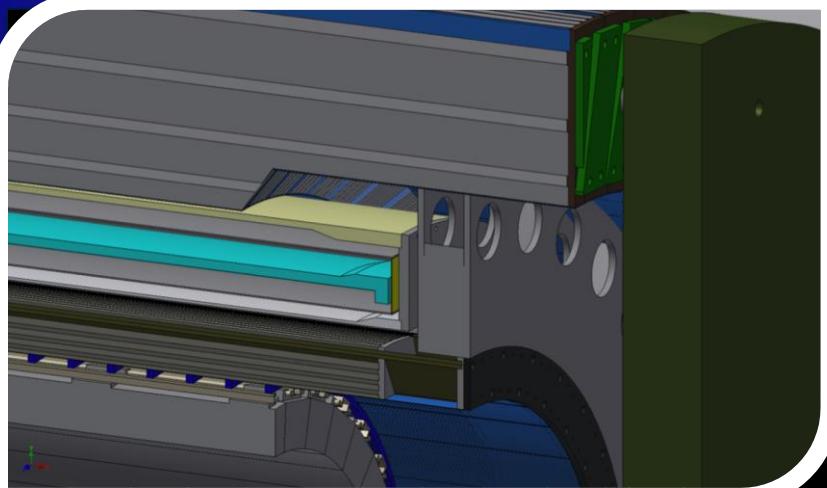
End-door design

By J. Huang, R. Ruggiero (BNL/PHENIX)
Presented: Jin, fsPHENIX meeting, Jan 20

Lampshade magnet



New forward spectrometer design ➤

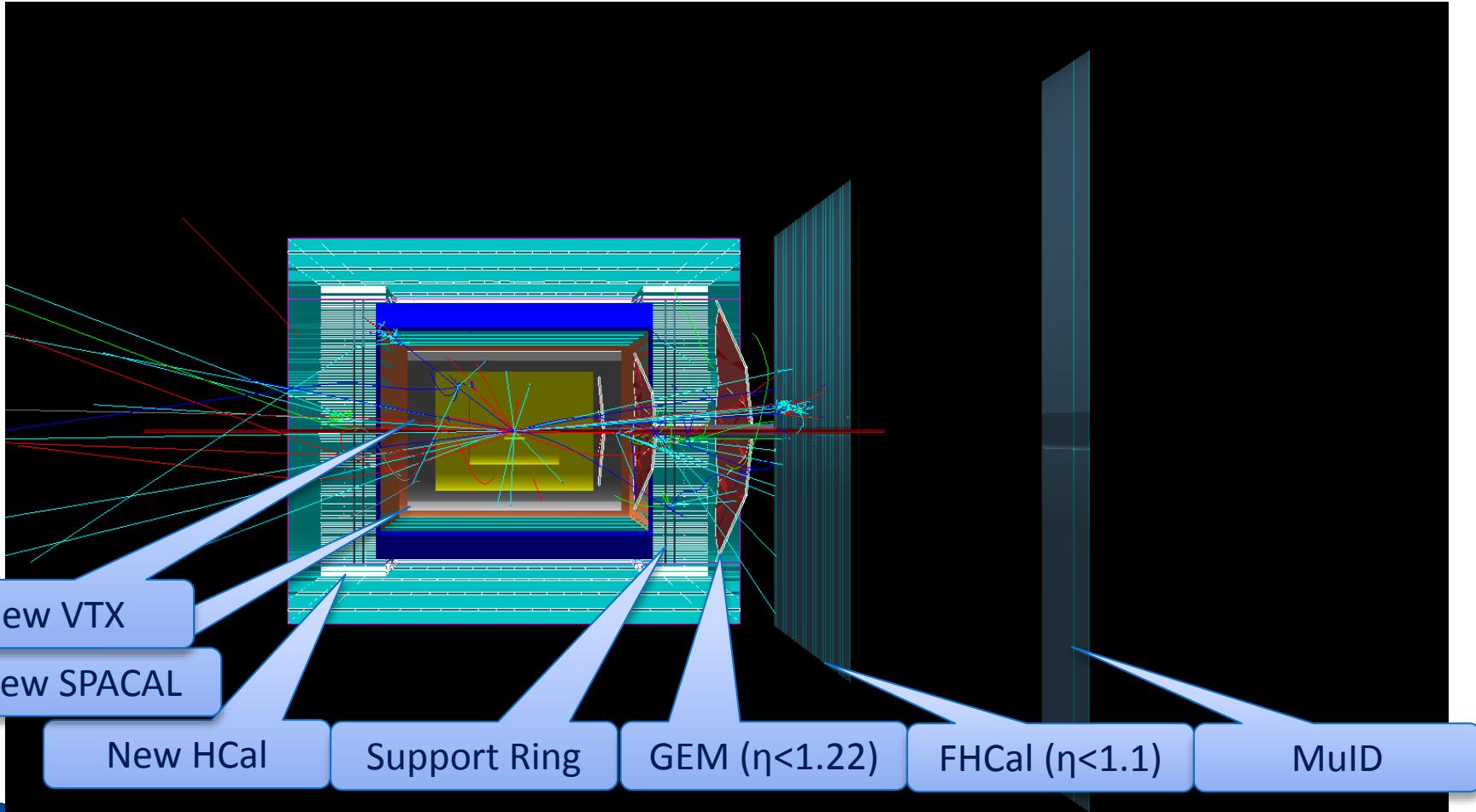


Detailed design >>

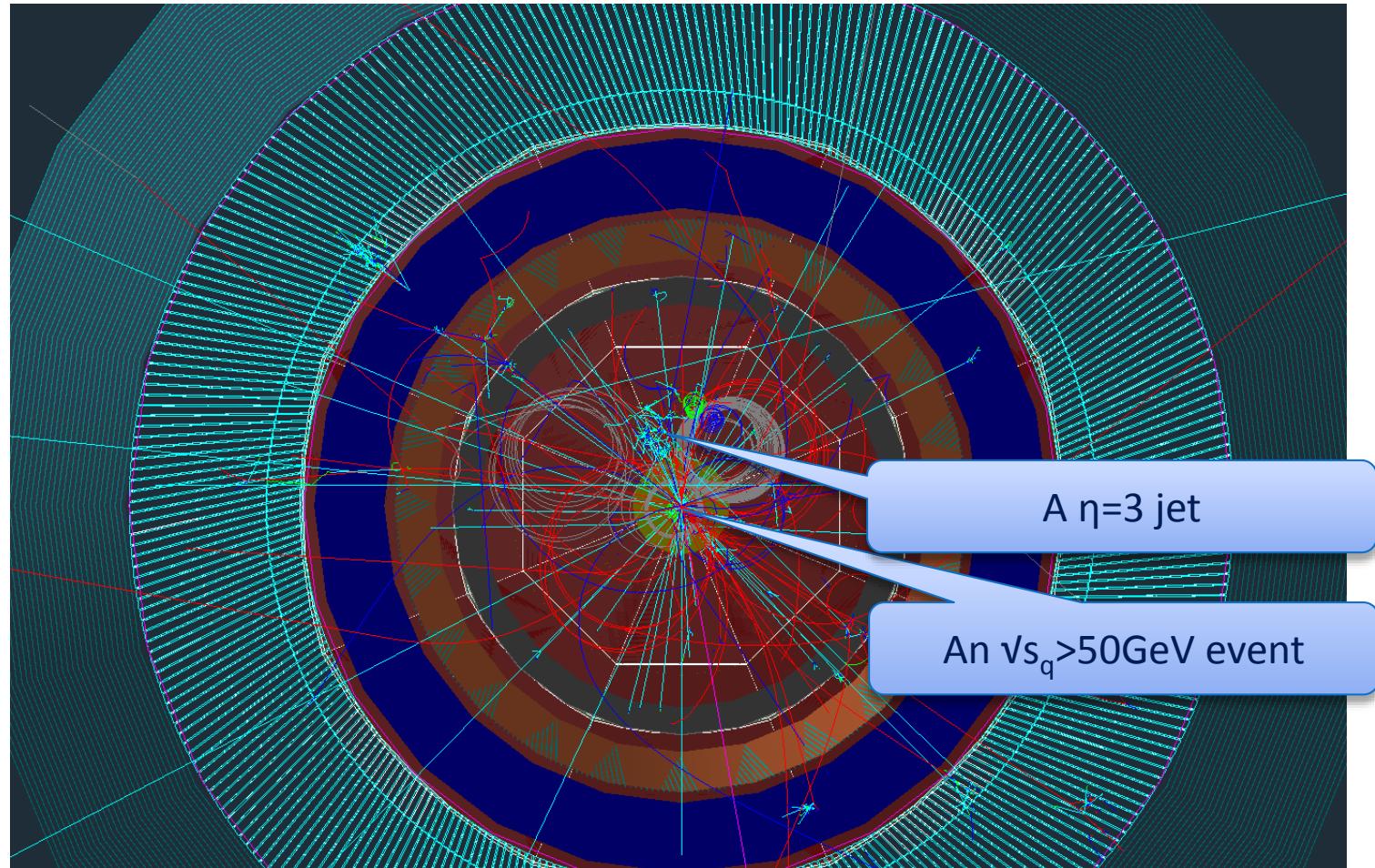
Boundary between sPHENIX and fs/ePHENIX can be well covered by hadron calorimeters for jet measurements. Forward tracking/PID likely start from eta=1.2

Presented: Jin, fsPHENIX meeting, Jan 20

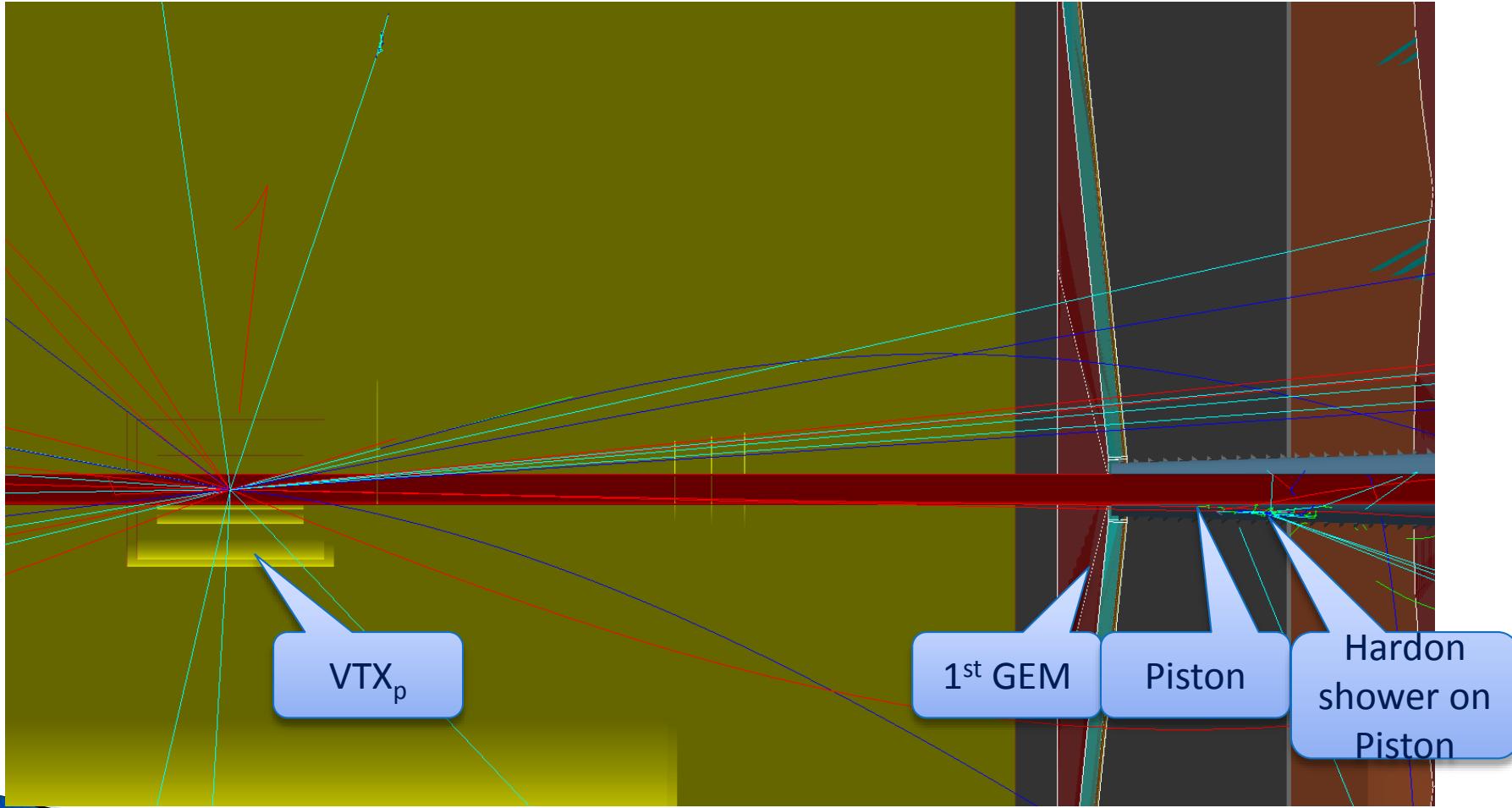
Updated Geant4 Model



New Geant4 Model



New Geant4 Model



Standardized Jet Analysis Tool Chain



Fun4All_G4_fsPHENIX() input param.

CVS:/simulation/g4simulation/macros/Fun4All_G4_fsPHENIX.C

Documentation:

https://www.phenix.bnl.gov/WWW/offline/doxygen/html/d7/d9e/Fun4All_G4_fsPHENIX_8C.html#a76aeb153ec36f57bd23996c1d6a7508a

Function Documentation

```
void Fun4All_G4_fsPHENIX ( int          nEvents = 10,  
                           int          nSkip = 0,  
                           const char * input_file = "test/ID1200_phpythia_jet_eta0_E4.root.1st",  
                           const char * embed_input_file = NULL  
                         )
```

fsPHENIX simulation loading script

Parameters

- [in] **nEvents** Number of events to run. If nEvents=-1, then a event display will be shown
- [in] **nSkip** Number of event to skip before start processing
- [in] **inputFile** Input file. Depending on the "Input options" as in the beginning of macro.
- [in] **embed_input_file** Second input file for embedding. Also depending on the "Input options" as in the beginning of macro.

Definition at line 12 of file [Fun4All_G4_fsPHENIX.C](#).

View newest version in PHENIX CVS at line 12 of file [Fun4All_G4_fsPHENIX.C](#)

References [PHMCTowerMerge::AddInputMCTower\(\)](#), [G4DSTReader::AddJet\(\)](#), [Fun4AllInputManager::AddListFile\(\)](#), [G4DSTReader::AddNode\(\)](#), [G4DSTReader::AddTower\(\)](#), [PHG4Reco::ApplyCommand\(\)](#), [Cemc_slats_per_cell](#), [RawTowerBuilder::Detector\(\)](#), [RawClusterBuilder::Detector\(\)](#), [PHG4SlatCellReco::Detector\(\)](#), [PHG4CylinderCellReco::Detector\(\)](#), [RawTowerBuilderCone::Detector\(\)](#), [PHG4CalEvaluator::Detector\(\)](#), [Fun4AllServer::End\(\)](#), [PHG4CylinderCellReco::etaphisize\(\)](#)

Fun4All_G4_fsPHENIX() input switch

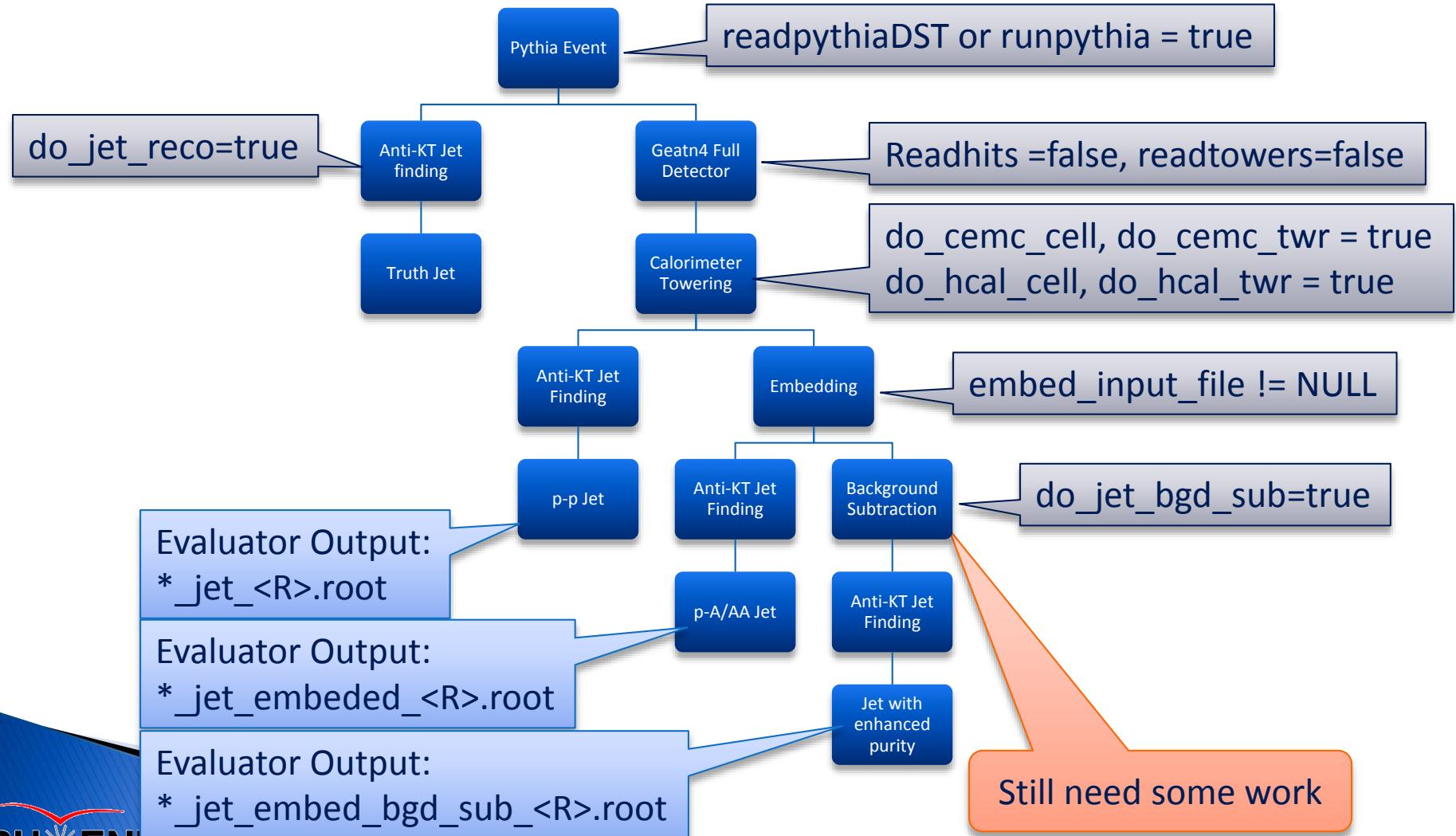
CVS:/simulation/g4simulation/macros/Fun4All_G4_fsPHENIX.C

```
//-----
// Input options
//-----
// Either:
// read previously generated g4-hits or g4-tower DST files, in this case it opens a DST and
skips
// the simulations step completely. The G4Setup macro is only loaded to get information
// about the number of layers used for the cell reco code
const bool readhits = false;
const bool readtowers = false; Read G4 hits/tower or run the simulation
// Or:
// read files in HepMC format (typically output from event generators like hijing or pythia)
const bool readhepmc = false; // read HepMC files HEPMC: sPHENIX standard
// Or:
// read DST files containing PHPythia nodes
const bool readpythiadst = true; // read PHPythia files PHENIX PhPythia DST
// Or:
// Generate pythia event
const bool runpythia = false; // read HepMC files Or run Pythia directly
// Run a event display automatically when nEvents<0
const bool event_display = (nEvents < 0 && !(readhits || readtowers)); // read HepMC files
// Save G4 raw info?
const bool save_g4_raw = readhits ? false: true;
```

nEvent<0 = show event display

Existing Tool Chain and flags

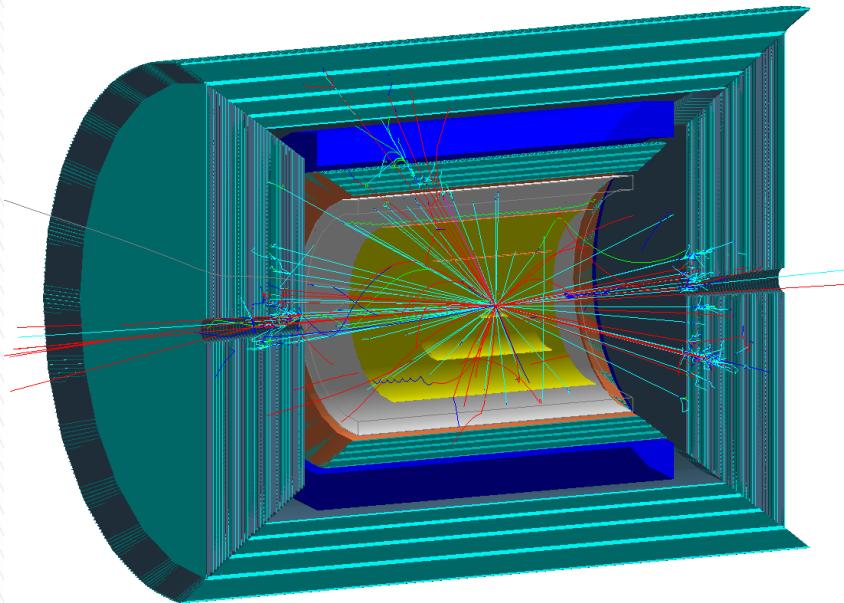
One can break at any stage, and pick up the progress again with same macro



An illustration with 2.5m FHCAL results

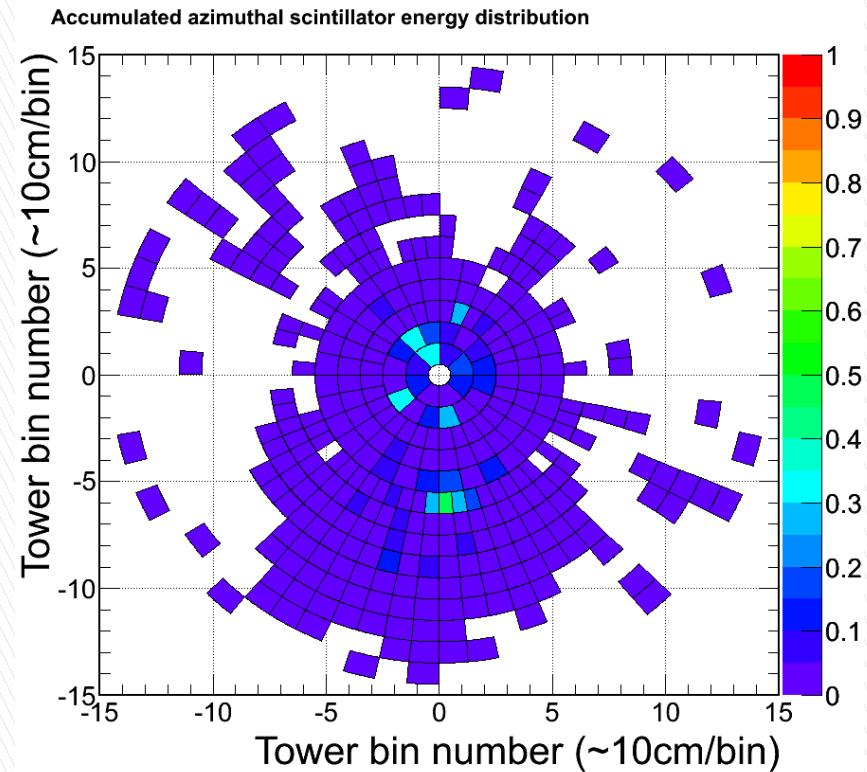
CVS:/simulation/g4simulation/macros/Fun4All_G4_sPHENIX_plus_fHCAL.C

- Towering of the FHCAL



Event display

2.5m FHCAL results



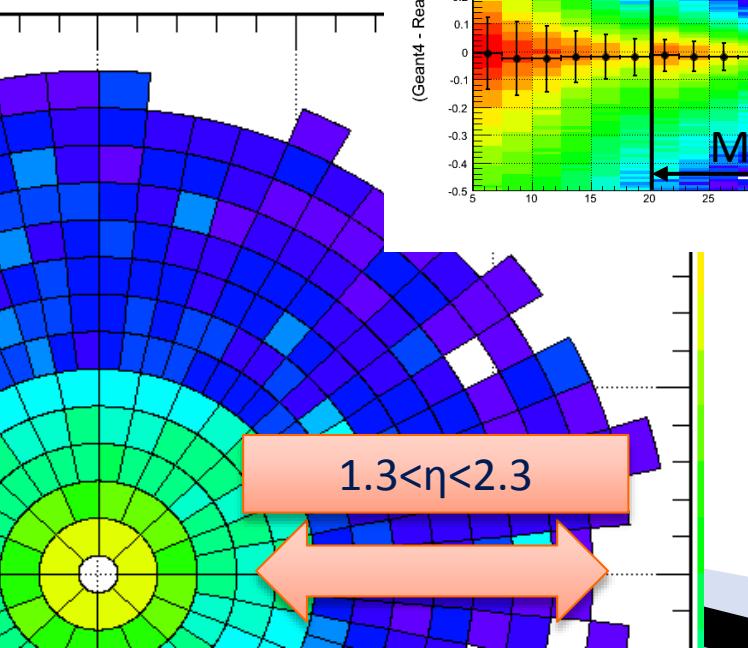
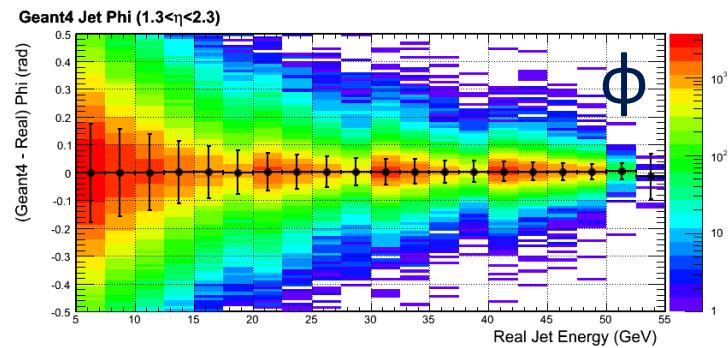
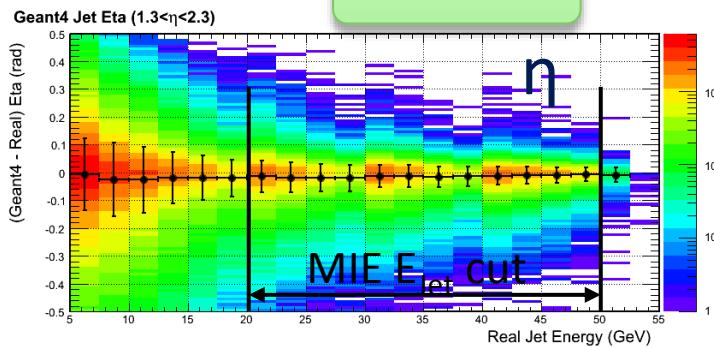
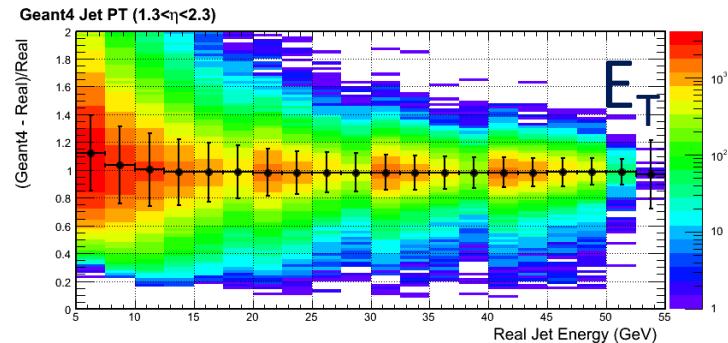
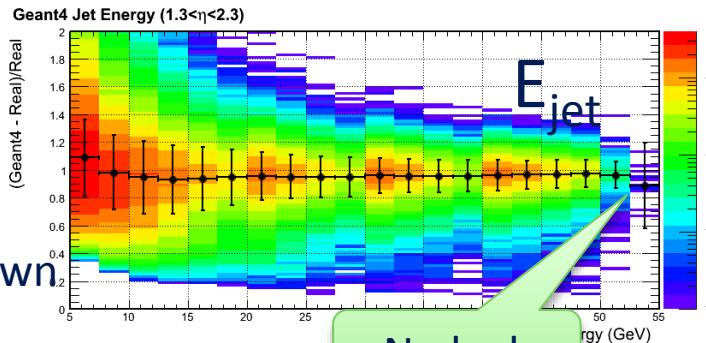
FHCAL Segmentation

Jet G4 simulation with 200GeV pp full event

– fHCAL central

2.5m fHCAL results

Anti kT w/ R=0.6
Pythia p+p 200GeV
Gaus fit μ and σ shown



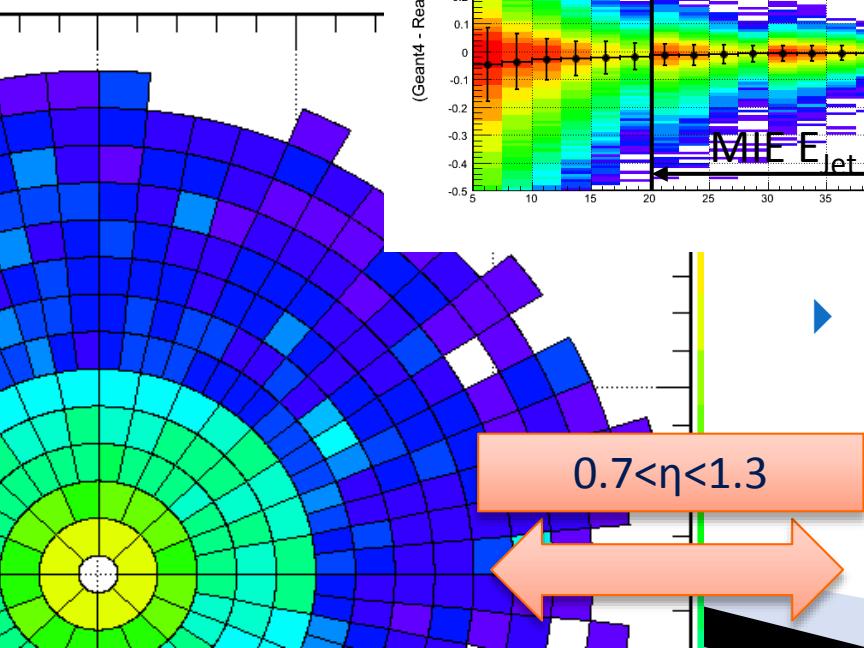
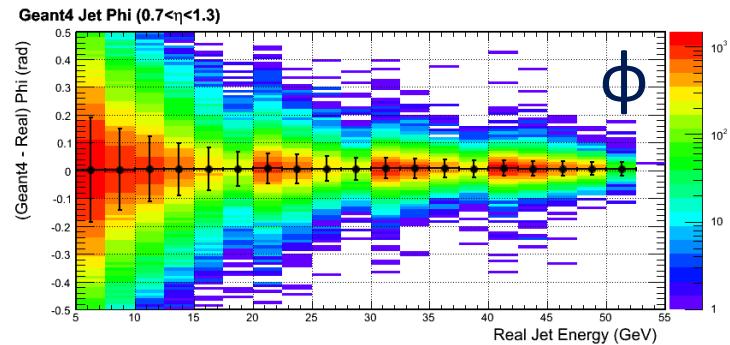
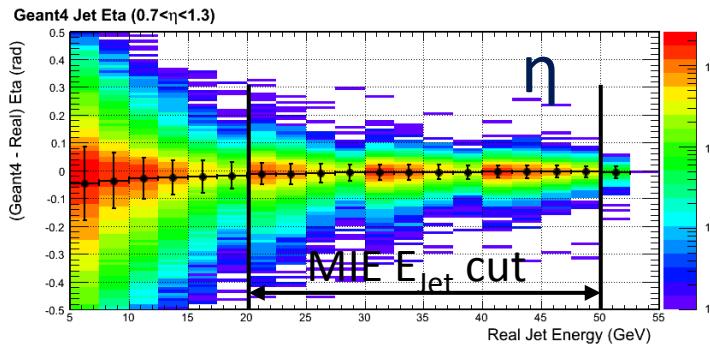
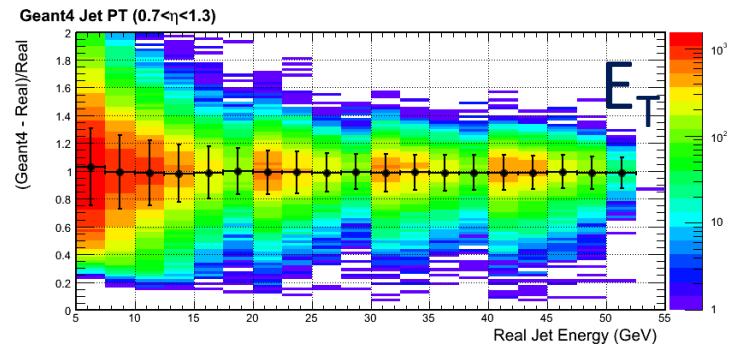
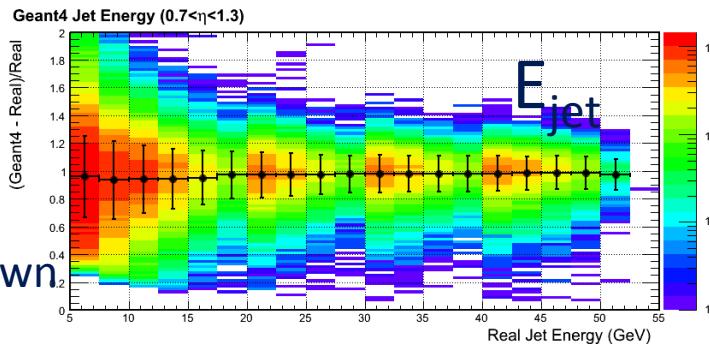
- ▶ In a good region where $d\phi = 0.1$ - 0.2 per tower
- ▶ Major part of the jet within fHCAL

Jet G4 simulation with 200GeV pp full event

– Connection to sPHENIX

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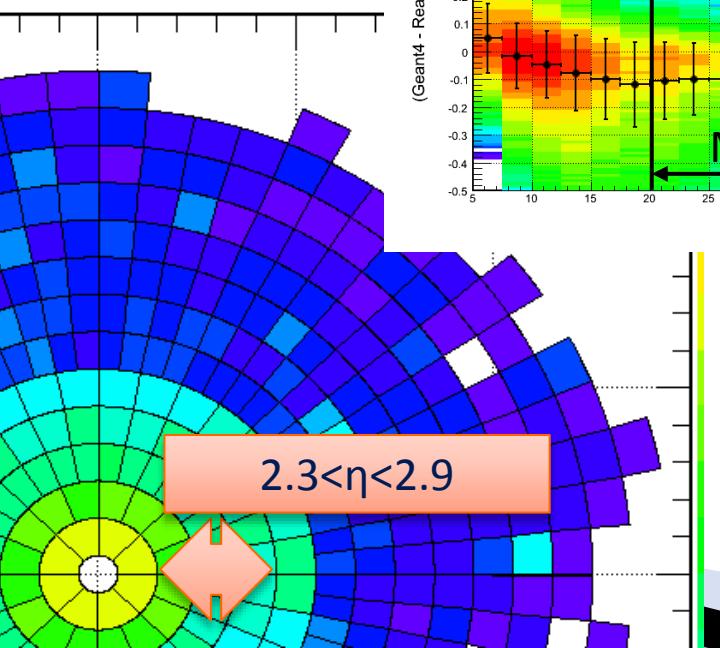
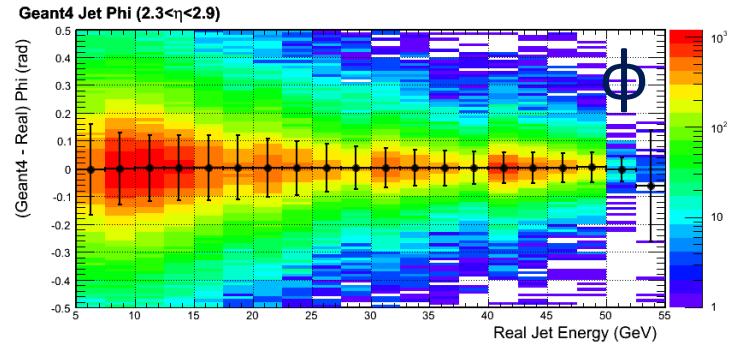
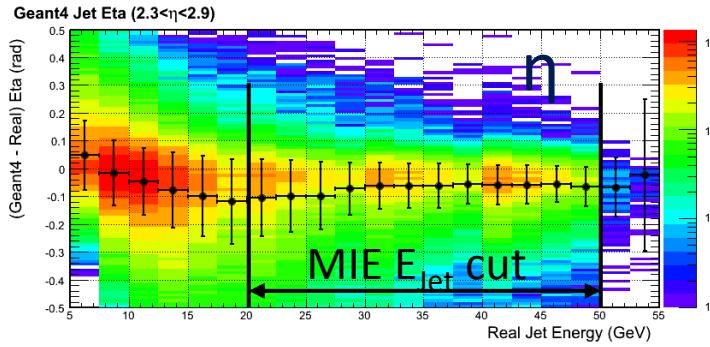
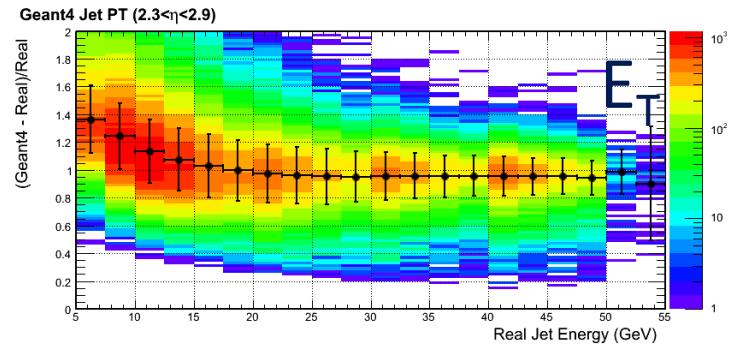
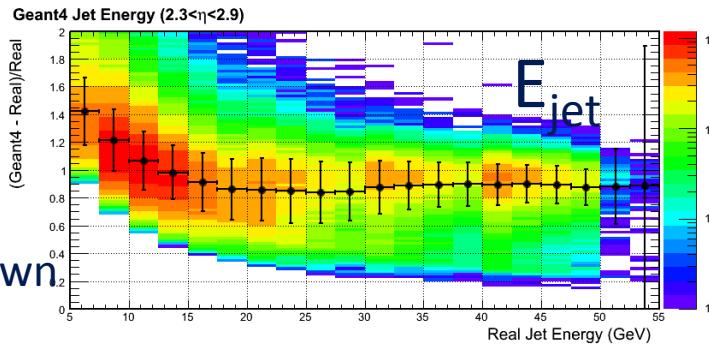


► Works by using
EMCal + 2 barrel Hcal + FHCAL

Jet G4 simulation with 200GeV pp full event – Towards beam line

2.5m FHCAL results

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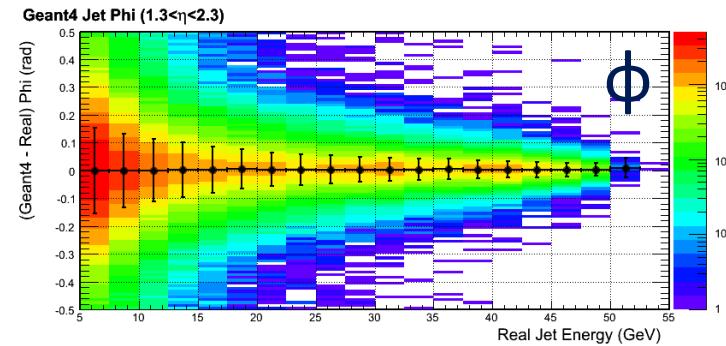
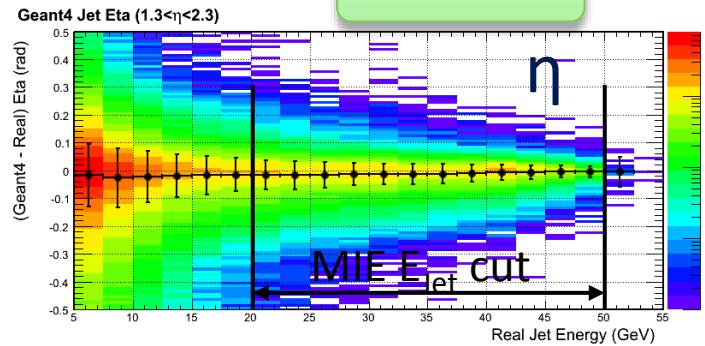
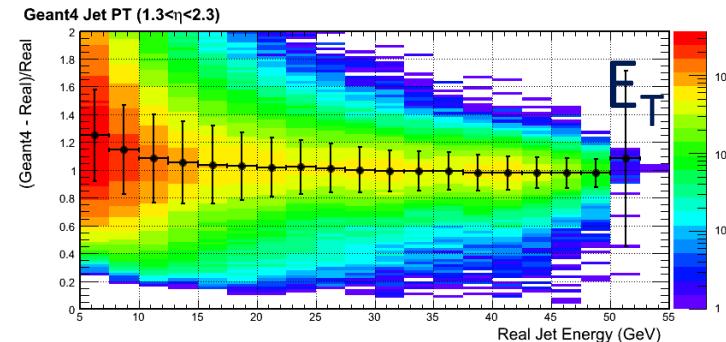
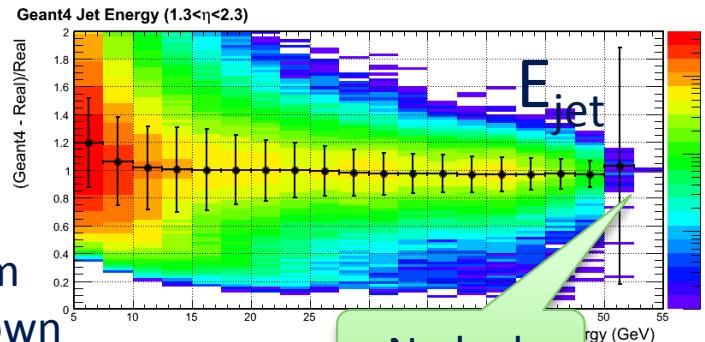
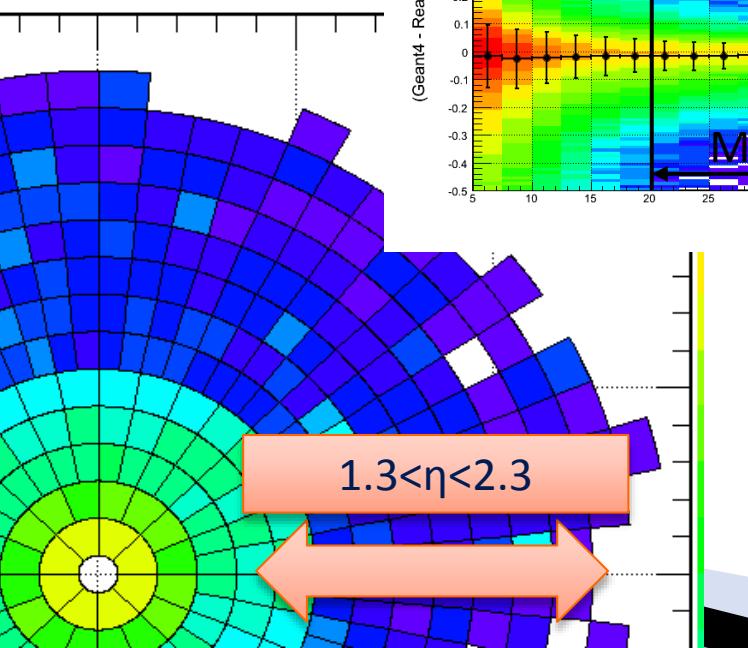
- ▶ Stronger bias on eta from binning effect
- ▶ Can be corrected by tricky
- ▶ At $\eta=3$, $E_{jet} = 20\text{GeV} \rightarrow E_T = 2\text{GeV}!$

Jet G4 simulation with pA Embedding

– fsHCal central

2.5m FHCAL results

Anti kT w/ R=0.4
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 + HIJING pA b=0-4fm
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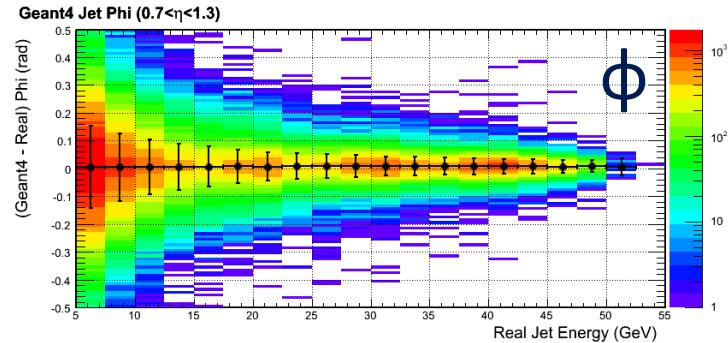
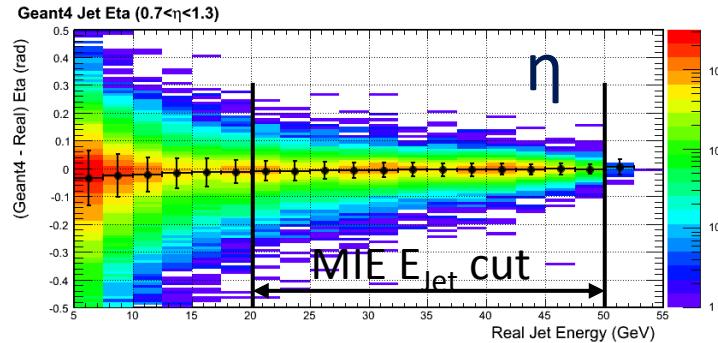
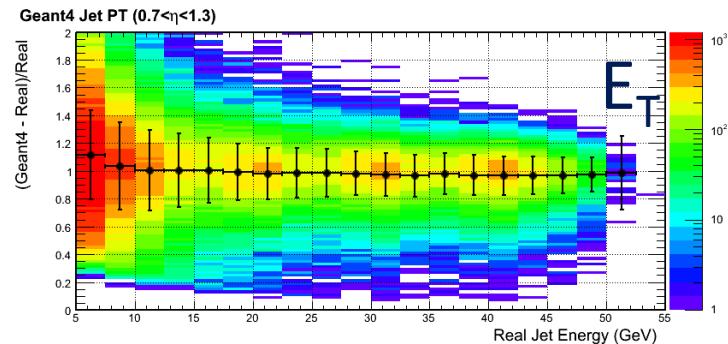
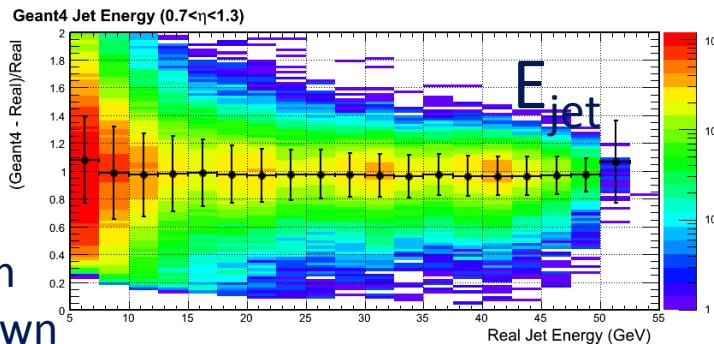
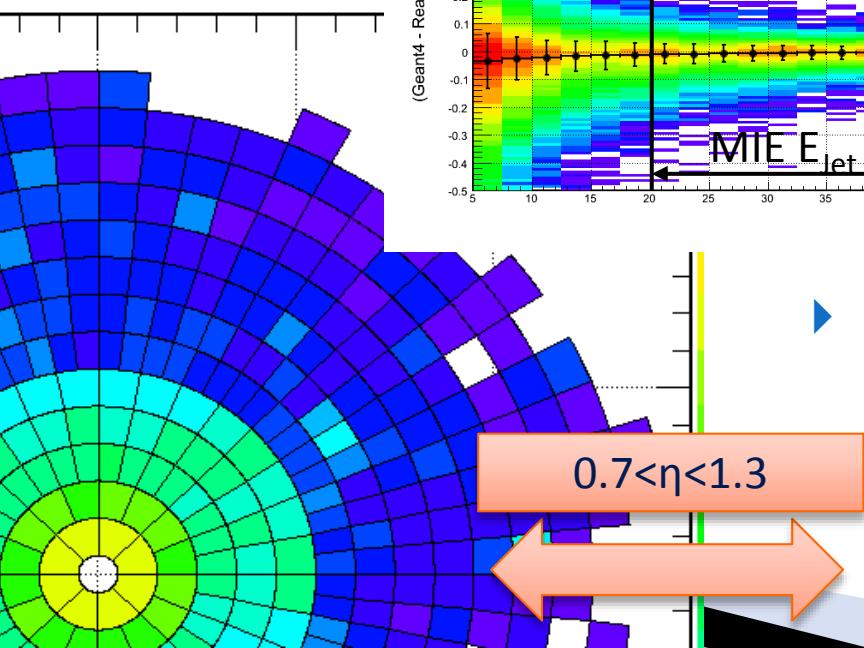
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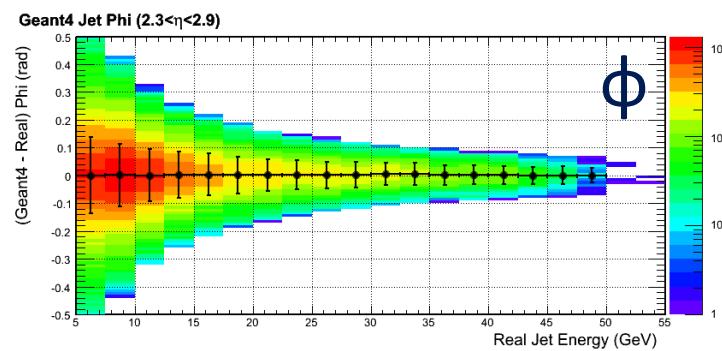
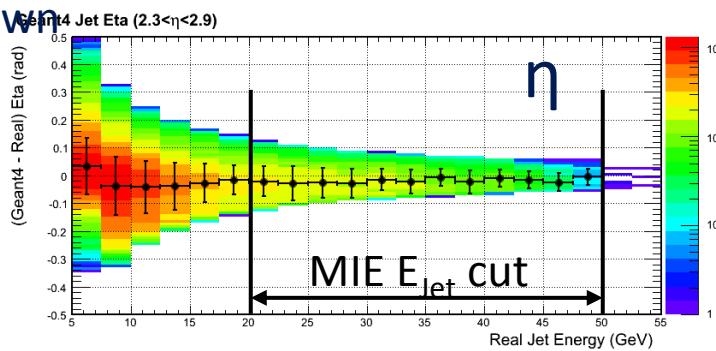
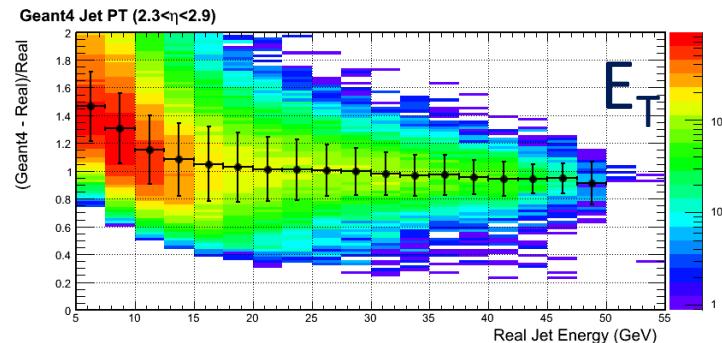
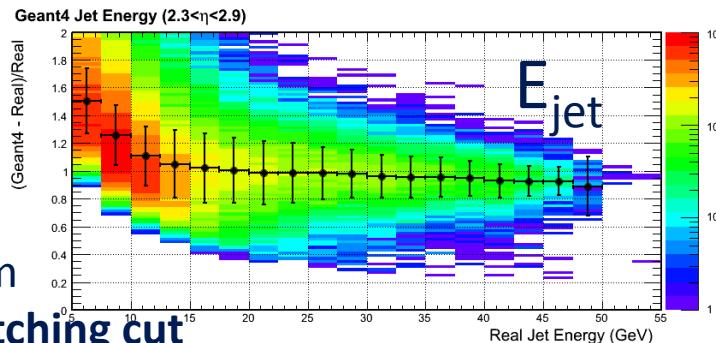
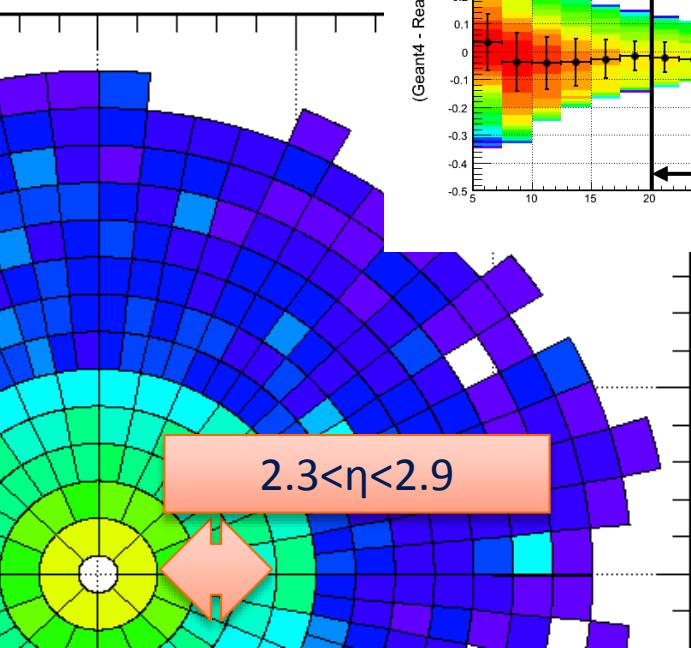
$0.7 < \eta < 1.3$

Jet G4 simulation with pA Embedding

– Towards beam line

2.5m FHCAL results

Anti kT w/ R=0.4
 Pythia p+p 200GeV
 + HIJING pA b=0-4fm
3 sigma eta-phi matching cut
 Gaus fit μ and σ shown



- ▶ Stronger bias on eta from binning effect
- ▶ Can be corrected by tricky
- ▶ At $\eta=3$, $E_{jet} = 20\text{GeV} \rightarrow E_T = 2\text{GeV}$!

2.5m Hcal summary

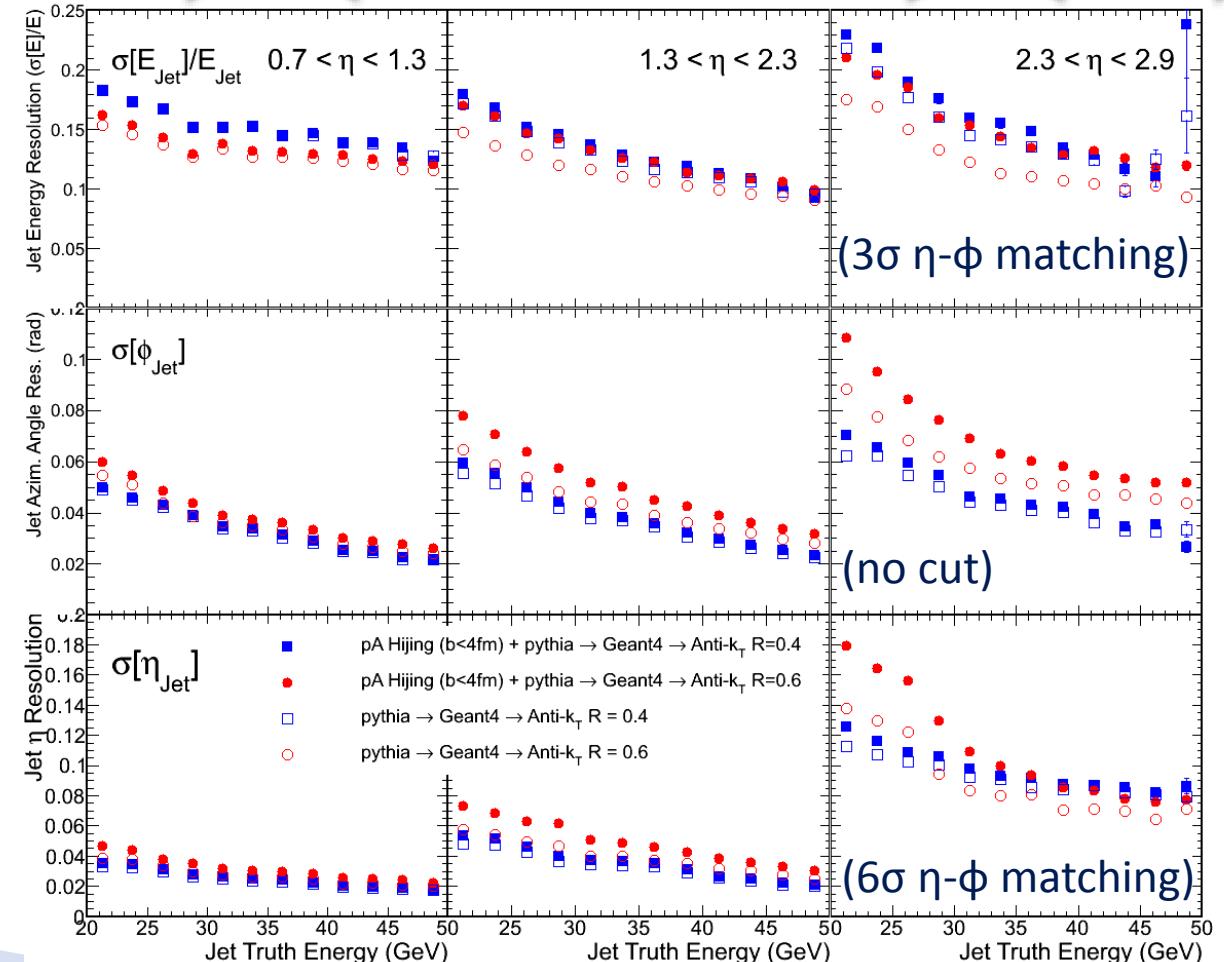
2.5m FHCAL results

- 3.5 m Hcal should do better

Presented: Jin, sPHENIX simulation meeting, Oct 31 2014

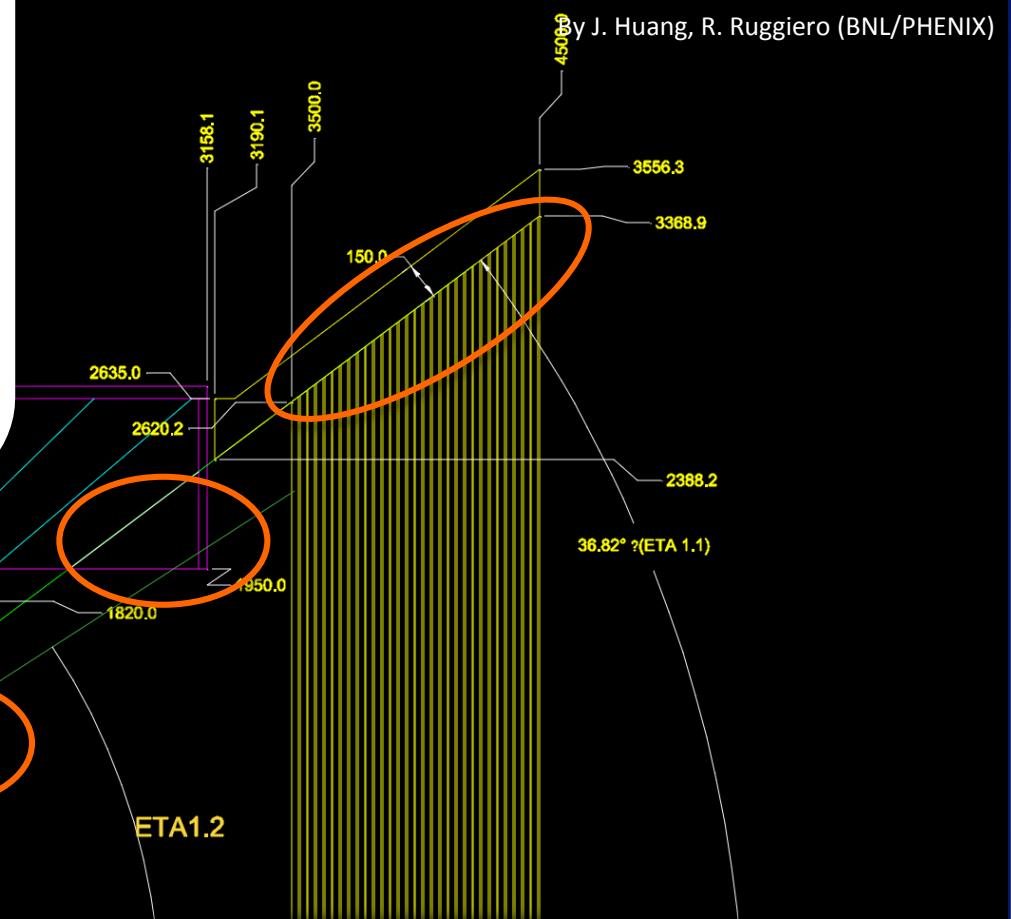
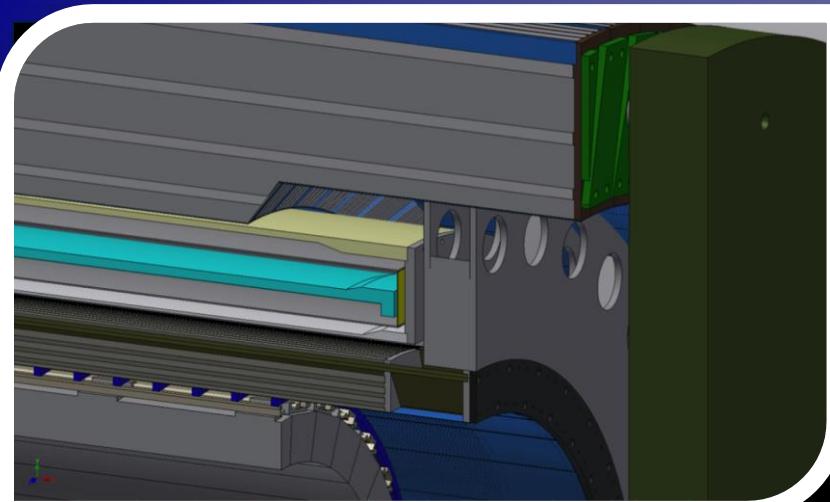


- ▶ R=0.6 is better for energy resolution
- ▶ R=0.4 is better for angular measurement and for pA
- ▶ Matching energy resolution in barrel for pp
- ▶ Good angular resolution
- ▶ Some complexity for
 - Energy matching barrel-forward join region
 - Angular resolution for very forward region



Jet Hermeticity

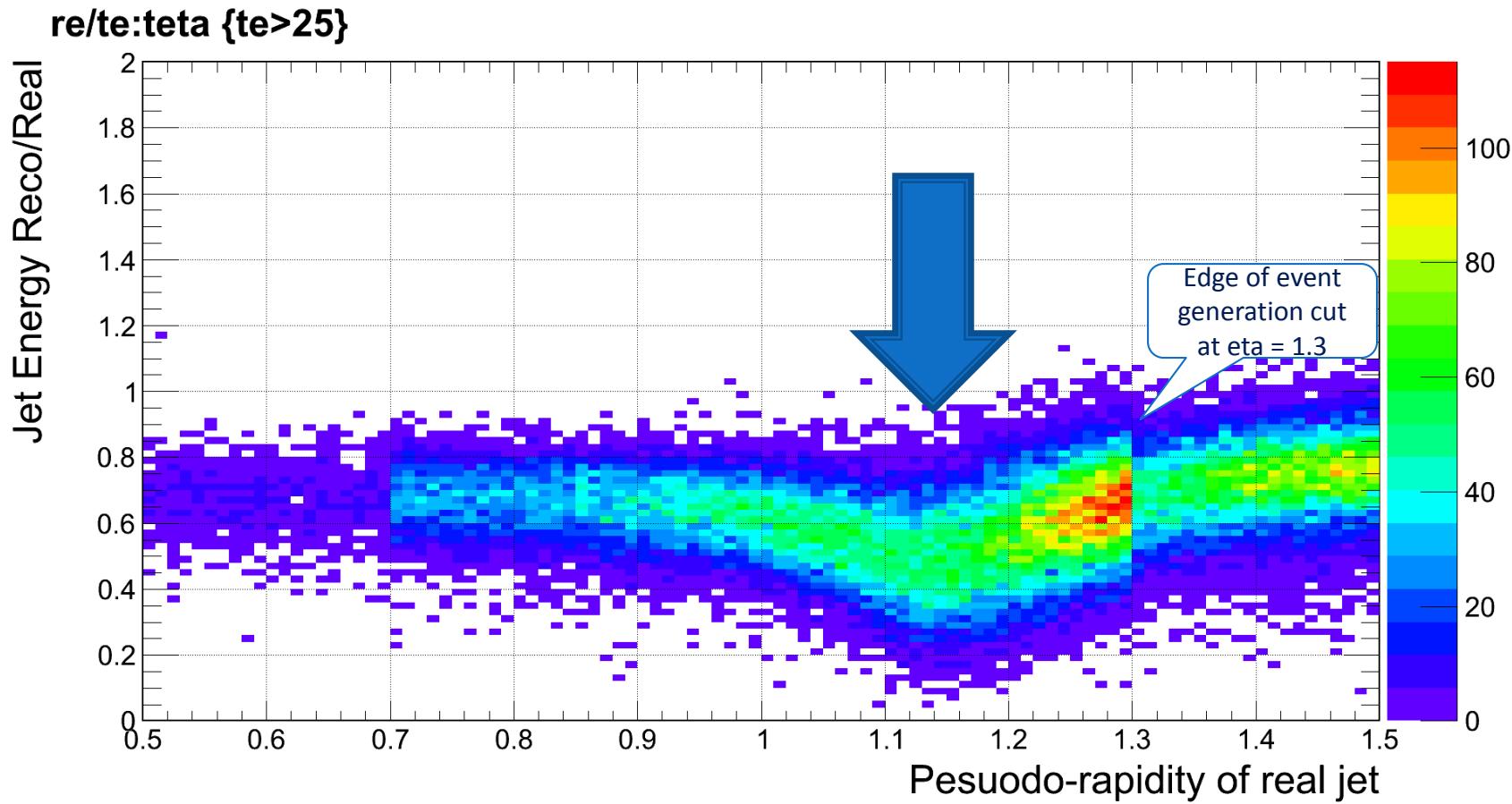




Would there be a jet coverage gap around $\eta=1$? ➤

We were asked when presenting the design
My guess is gap is minimal by summing all four calorimeters
Finished Geant4 Jet production, close to quantify this effect

Geant4 Result: The missing central HCal piece produce a minor dip in jet energy response



Jet Isolation



Summary for preliminary studies

2014 Preliminary, Pythia level only

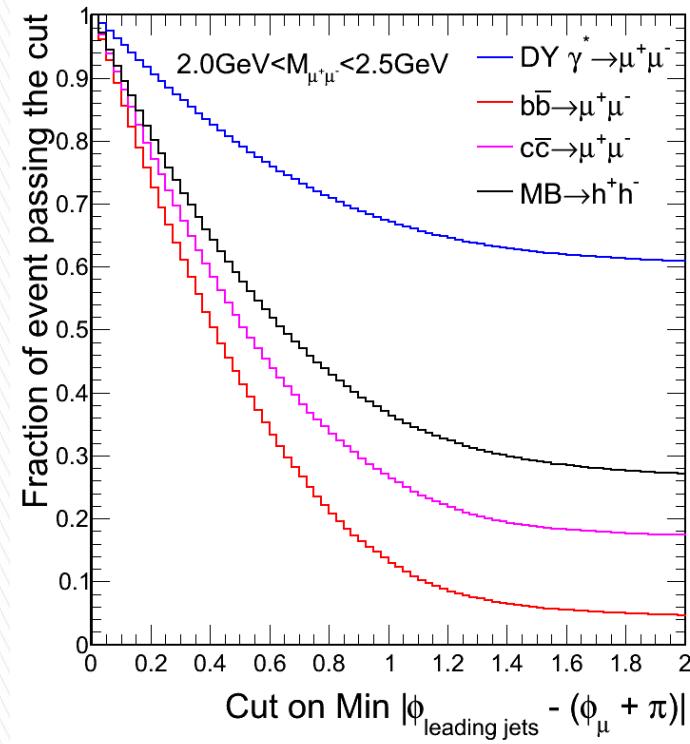
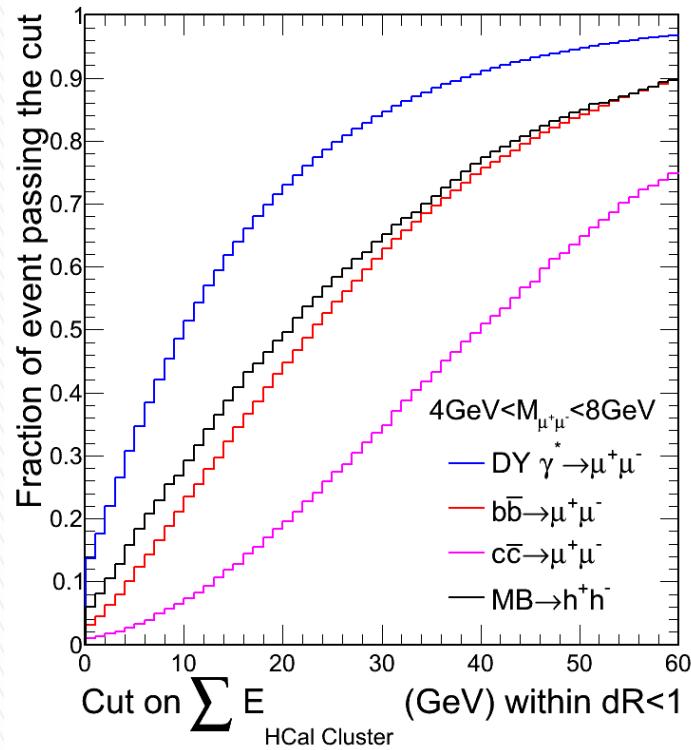
Presented by Jin & Cesar, June 10, 2014

Cuts	Relative Rejection @ 90% DY Eff	Relative Rejection @ 50% DY Eff
Track multiplicity near the muon candidate	2-3	2-4
Hcal energy deposition near the muon candidate	Moderate-factor of 2	2-10
LHCb-type jet-cone isolation	Moderate-factor of 2	2-10
Distance between nearest jet near and the muon candidate	Moderate-factor of 2	2-6
Angle correlation between backward going jet and the muon candidate	moderate	2-3 for high mass 2-10 for low mass

Summary for preliminary studies

2014 Preliminary, Pythia level only

Presented by Jin & Cesar, June 10, 2014



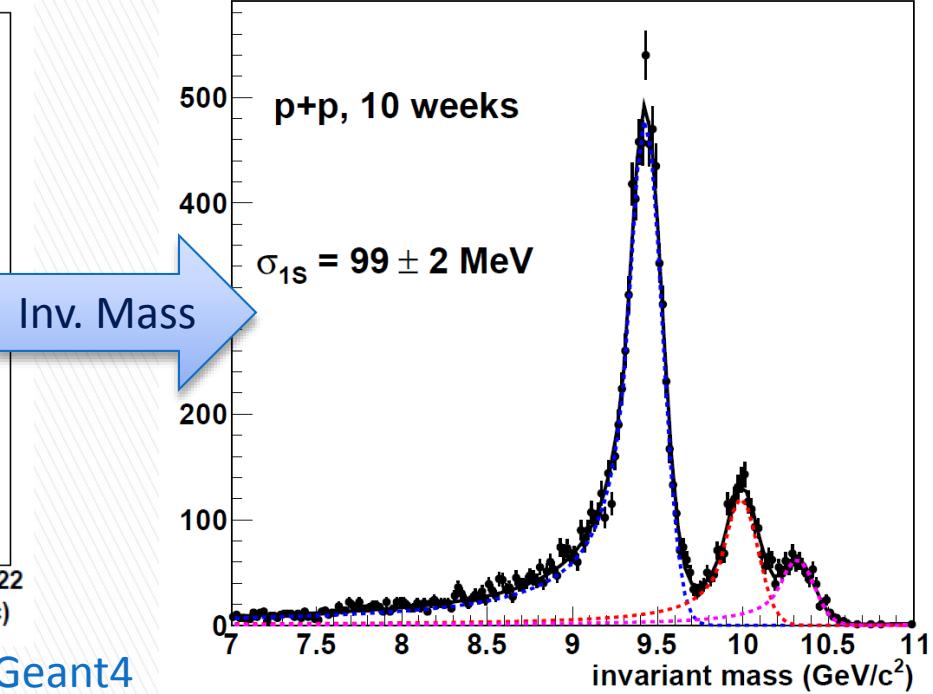
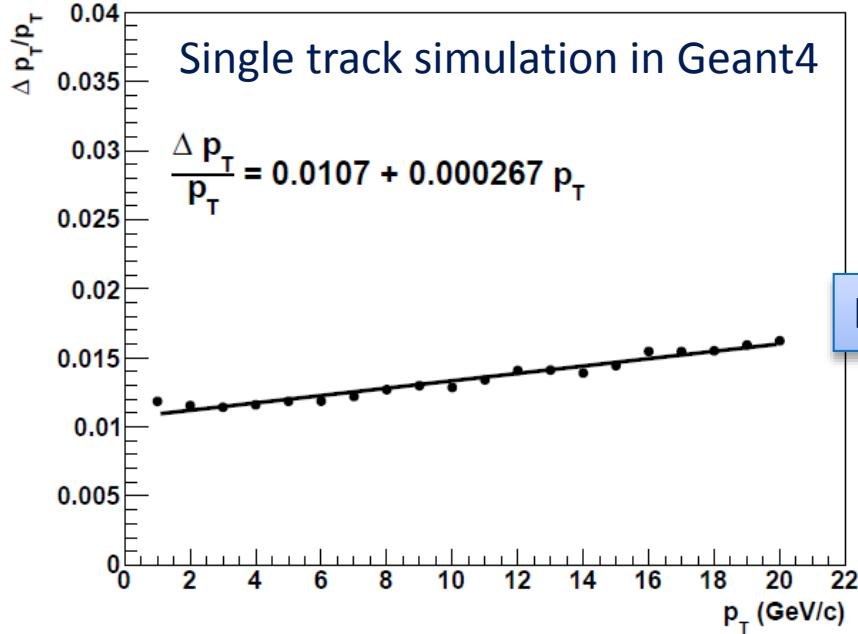
High mass region in 510pp:
HCal jet-cone isolation cut

Low mass region in 510pp:
Back-to-back jet-veto cut

Summary

- ▶ Forward Jet tool chain in Geant4 were developed for the Nov-2014 sPHENIX proposal
- ▶ Ready for study in full Geant4 simulation for
 - Sivers/Collins projection, resolution effect, background effect
 - Jet, Di-Jet A_{LL}
 - Jet isolation for DY measurement
 - W->Di-Jet with both Jet pt-weighted charge tagging??
- ▶ Also forward arm design was updated with the new sPHENIX, Geant4 simulation was updated too
- ▶ Both new geometry and analysis chain built in the default macro and submitted to CVS:
[Fun4All_G4_fsPHENIX\(\)](#) in
CVS:/simulation/g4simulation/macros/[Fun4All_G4_fsPHENIX.C.](#)

Tracking : Performance in Geant4

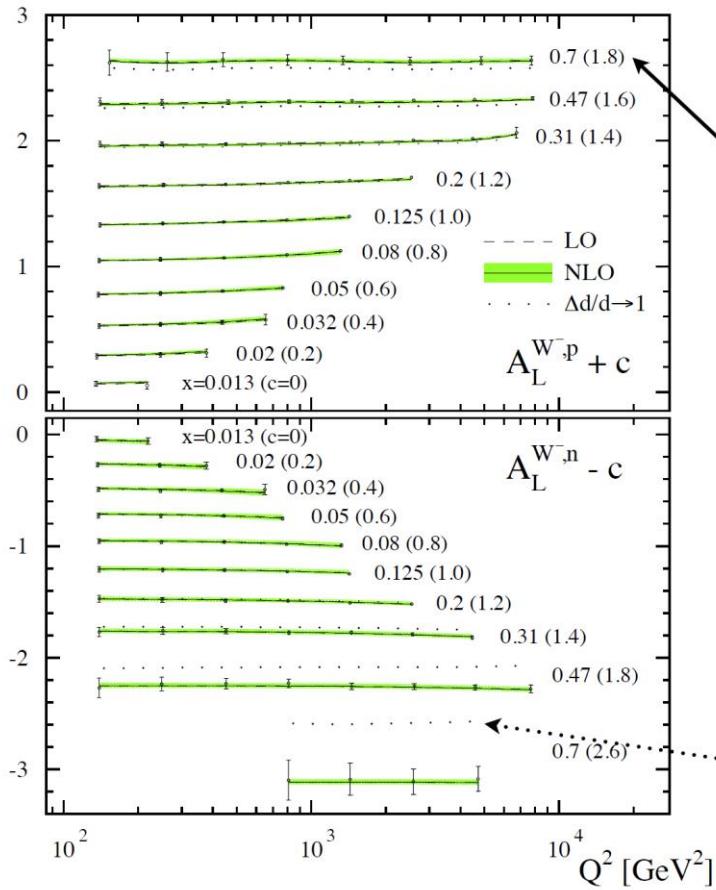


Also full detector HIJING simulation in Geant4
Eff. = 92% at 1 GeV/c and 97% at high p_T .

Single track performance

Invariant mass for e^+e^- pairs

EIC W simulation

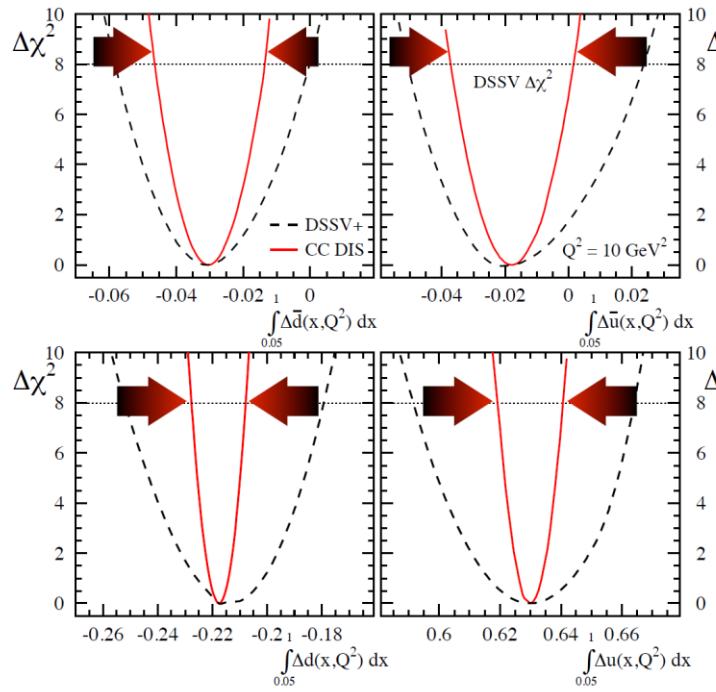


A_L^W results

- Large A_L^W at large $x \sim 80\%$
- NLO effects small
- $\sigma(A_L^W)/A_L^W$ small
 - ▶ $<\sim 5\%$ for **p**
 - ▶ $<\sim 8\%$ for **n**
 - ▶ $\sim 25\%$ at x limits
- Sensitive to “helicity retention”

EIC W simulation

Impact on global analyses



- Constrain **u**, **d** & **anti-q** helicities
- Flavour constraint independent of **fragmentation**
- Important cross check on **SIDIS**
 - ▶ low Q^2 , higher twist effects